California Late Cretaceous Donaciform Bivalves

by

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Abstract.   California donaciform bivalves of Late Cretaceous age occur sporadically, but locally abundantly, in coarse-grained sandstone. Where abundant, they indicate near strand-line deposition. Seven species are allocated among a new genus, *Adelodonax,* and a new subgenus, *Aliodonax,* in the Donacidae and a new genus, *Califadesma,* in the Mesodesmatidae. The donacids are *Notodonax* (*Aliodonax*) *hsui* sp. nov. of Santonian age, *N.* (*A.*) *bolsae* sp. nov. of Campanian age, *Adelodonax tectus* sp. nov. of Santonian age, and *A. altus* (Gabb, 1864) of Maastrichtian age; the mesodesmatids are *Califadesma aspris* sp. nov. of Coniacian age, *C. elaphium* sp. nov. of Santonian age, and *C. tuscanum* sp. nov. of Campanian age.

Mactropsis Conrad, 1854, is a mactrid rather than a mesodesmatid. *Myadesma* Clark, 1922, is an anomalodesmacean and *Ceroniola* Wilckens, 1904, may be a donacid; both are excluded from the Mesodesmatidae and from the Mactracea.

INTRODUCTION

Although donacid bivalves have been recognized elsewhere in the Cretaceous, neither donacids nor mesodesmatids have previously been recorded from the California Cretaceous. Abundant donaciform bivalves from the Musty Buck Member of the Chico Formation at about 44 m above the base of the section on Chico Creek, Butte Co., California, proved, upon exposure of hinge lines, to belong to three genera in the Donacidae and Mesodesmatidae.

Cretaceous Donacidae include *Notodonax* (Feruglio, 1936) from the Maastrichtian of Argentina, and *Protodonax* (Vokes, 1945) proposed for species of Albian through Maastrichtian age from the Western Interior and Atlantic Coast of North America as well as the Aptian of Lebanon. STEPHENSON (1952) added two Cenomanian species from the Gulf Coast to *Protodonax.* The family has thus been recognized in the Early Cretaceous. The five California species herein added to the family range in age from Santonian to Maastrichtian. These species are more similar to Maastrichtian species from Chile and Argentina than to species described by VOKES (1945) and STEPHENSON (1952) from North America and the Near East.

The earliest mesodesmatid listed in the *Treatise on Invertebrate Paleontology* (Keen *in* MOORE, 1969) is *Ceroniola* Wilckens, 1904, from the Quiriquina Formation of Late Cretaceous age. WILCKENS (1904) apparently placed *Ceroniola* in the Mesodesmatidae because he considered the triangular depression beneath the beaks to be a resilifer, but the hinge teeth of *Ceroniola* show no relationship to those of *Mesodesma* Deshayes, 1832. *Ceroniola* is, as indicated by BEU (1971:124), an improbable ancestor for *Mesodesma.* Similarities between *Ceroniola* and *Adelodonax* gen. nov. suggest that *Ceroniola* may be a donacid.

The next oldest purported mesodesmatid (Keen *in* MOORE, 1969) is *Mactropsis* Conrad, 1854, from the Eocene of Alabama. DALL (1898:907) placed *Mactropsis* in the Mesodesmatidae because it has a very thick shell. He inferred that mesodesmatids were unlikely to be recognized earlier than Tertiary because of the stage of hinge development in *Mactropsis,* but *Mactropsis* appears more closely related to the mactrid *Spisula* Gray, 1837, than to *Mesodesma.*

The next younger genus included by Keen (*in* MOORE, 1969) in the Mesodesmatidae is *Myadesma* Clark, 1922, of Eocene to Miocene age from the Pacific Northwest. The lack of striated laterals and the probable lithodesma (CLARK, 1922) found within its chondrophore are sufficient to exclude it from Mesodesmatidae. BEU (1971) agrees with CLARK (1922) in placing it in Myadesmatidae but retains this family within the Mactracea. The rough and lamellar shell texture of *Myadesma* is more like that of *Entodesma* (*Agriodesma*) *saxicolum* Baird, 1863, of the Lyonsiidae, and the hinge structures resemble those of Periplomatidae. The tooth beneath the beak in each valve was interpreted as a cardinal by BEU (1971), but these are unduly inconstant for veneroid cardinal teeth and are not of mactracean form. Myadesmatidae has more in common with the anomalodesmacean families Lyonsiidae and Periplomatidae.
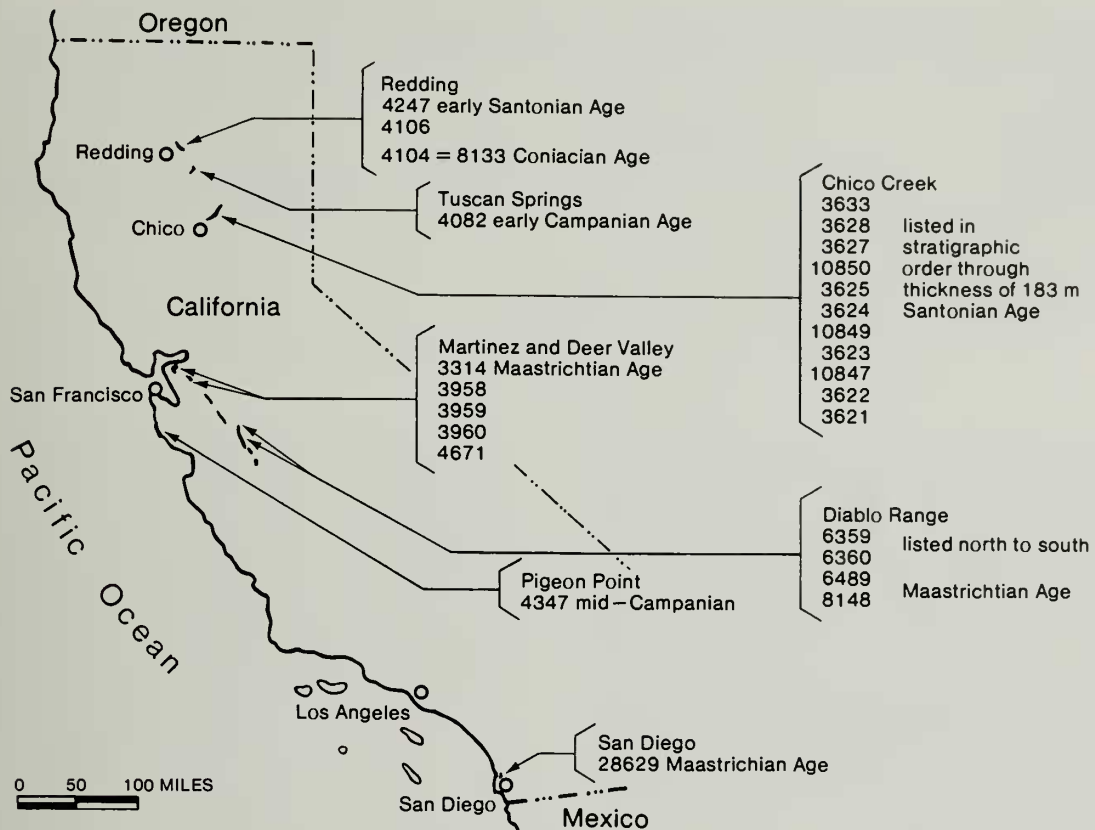
Figure 1

Index map to seven areas in California that have yielded donaciform bivalves of Late Cretaceous age. Localities listed for each area are described, or a reference to a description is given in Appendix 1—Localities Cited.

The hinge of the new genus *Califadesma* differs from that of *Mesodesma* Deshayes, 1832, in being less advanced but is indubitably that of a mesodesmatid. Unlike the hinge of *Mactropsis aequorea* (Conrad, 1833) (Figures 43, 44) with its resemblance to *Spisula*, the hinge of *Califadesma* is clearly homologous to those of Recent species of *Mesodesma*, such as *M. donacium* (Lamarck, 1818) (Figures 50, 51), *M. mactroides* Deshayes, 1855, and *M. (Ceronia) arctatum* (Conrad, 1830) (Figures 45, 46) and to those of the East Coast Miocene, *M. (C.) mariana* Glenn, 1904, and Pliocene, *M. (C.) spatha* Gardner, 1944. *Califadesma* is related to typical *Mesodesma* rather than to *Paphies* Lesson, 1831, which has smooth laterals and an austral distribution beginning as early as the early Miocene (BEU, 1971:117; BEU & DE ROOIJ-SCHUILING, 1982:212). *Califadesma* is thus the oldest known mesodesmatid.

Abbreviations used with locality and catalogue numbers are: ANSP, Academy of Natural Sciences of Philadelphia; CAS, California Academy of Sciences; CIT, California Institute of Technology; LACM, Natural History Museum of Los Angeles County, Malacology; LACMIP, Natural History Museum of Los Angeles County, Invertebrate Paleontology; UCB, University of California, Berkeley; UCBMP, University of California, Berkeley, Museum of

Paleontology; UCLA, University of California, Los Angeles.

DISTRIBUTION

The presence of both donacids and mesodesmatids in the California Upper Cretaceous is sporadic, and although specimens are abundant at some localities, they do not commonly constitute a major element of the faunas. They are abundant low in the Musty Buck Member of the Chico Formation on Chico Creek, Butte Co.; in a few beds of the Great Valley Series near Martinez and in Deer Valley, Contra Costa Co.; and in the Cabrillo Formation on Mt. Soladad, San Diego Co., California. They are locally common in the Redding Formation on the north side of Oak Run, Shasta Co., and in some beds of the Garzas Member of the Moreno Formation, Stanislaus Co., California. Donaciform bivalves, collected from localities in the seven areas indicated on Figure 1, have been studied for this report (see Appendix 1 for descriptions of localities). All of the mesodesmatids are from outcrops on the east side of the Sacramento Valley of northern California. Donacids occur with mesodesmatids in the northern California outcrops and additionally in central and southern California.
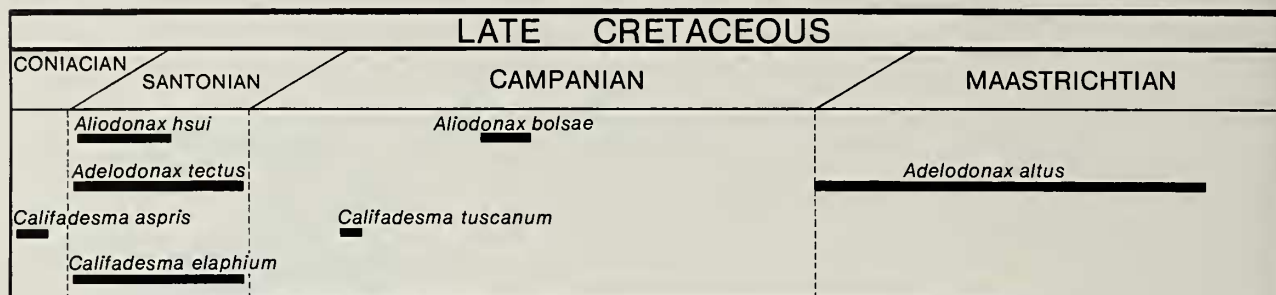
Figure 2

Geologic range chart for California Cretaceous species of Donacidae and Mesodesmatidae discussed in this paper.

The modern species of *Mesodesma* such as *M. donacium* of the Chilean coast and *M.* (*Ceronia*) *arctatum* of the northwest Atlantic coasts inhabit beaches to the south and north of the tropical to temperate donacids. Whether these Cretaceous records reflect a similar cooler water distribution for the mesodesmatids than for the donacids in the past or result from random preservation of sandy beach habitats is unclear.

Donacids are also longer ranging through the California Late Cretaceous than mesodesmatids. The presently known range of *Califadesma* is only from Coniacian through early Campanian, but that of the donacids is from Santonian into the late Maastrichtian. The geologic ranges of the species are shown in Figure 2.

Both *Notodonax* (*Aliodonax*) spp. and *Califadesma* spp. have relatively thick shells. An anteriorly compressed and posteriorly inflated shell, in several families, is an adaptation toward rapid burrowing (STANLEY, 1970), common among bivalves that frequently need reburying because they inhabit littoral substrates close to and within the surf zone. Rapid burrowers with thick shells (*Tivela, Mesodesma,* and *Donax*) occupy coarse, shifting substrate, where stability is essential (STANLEY, 1970:93).

Shells of *Adelodonax* spp. are of less than average thickness for donacids, and the paired valves have a more elongate, blade shape, which is efficient for rapid burrowing (STANLEY, 1970:59; VERMEIJ, 1987:312). Both sediment type and geologic occurrence agree with the morphologic implications of these clams and indicate that an abundance of either of these mesodesmatids or donacids is suggestive of a nearby shoreline.

Because the fossil record for such near-shore dwellers is relatively poor, VOKES (1945) expressed surprise at the number of Cretaceous donacid specimens that he was able to find. Most Cretaceous donacids have been described from the Atlantic basin; none of the species described from the Atlantic basin is closely related to the California species. California donacids resemble Maastrichtian species described from southern Argentina and Chile, and the mesodesmatids resemble typical late Cenozoic mesodesmatids of the Chilean coast. The lateral teeth of *Califadesma* are striate in the same manner as are those of *Mesodesma*

donacium (Lamarck, 1818) (BEU & DE ROOIJ-SCHUILING, 1982:figs. 2b, c) and *M. mactroides* Deshayes, 1855, in that the dorsal sides of the laterals are more strongly striate than the ventral sides.

NARCHI (1981) indicated that paleontological records place the origin of the mesodesmatids in Australasia, but the geologically oldest is of Miocene age (BEU, 1971; BEU & DE ROOIJ-SCHUILING, 1982). *Mesodesma* is reported in the late Pliocene of Chile (HERM, 1969:94); it is inferred to have dispersed along the Patagonian coast during the Pleistocene, and *M. mactroides* to have only recently moved northward into Brazilian shores (NARCHI, 1981). The northern California specimens suggest a northern origin for the ancestors of typical *Mesodesma* and its north Atlantic subgenus *Ceronia* Gray, 1853.

Califadesma is first recognized in the Coniacian. Northern California Coniacian and Santonian faunas appear to reflect a cooler regime than do the earlier Turonian molluscan faunas or the later Campanian faunas (SAUL, 1986). *Califadesma* may have moved into northern California with the cooler water and left with the return of warmer water. *Califadesma* is a creditable ancestor for *Mesodesma,* despite the considerable time gap between the Late Cretaceous disappearance of *Califadesma* and the late Pliocene appearance of *Mesodesma.* The improbability that *Donacilla* (*Mesodesma*) *sakhalinensis* Kalishevich, 1967, from the late Eocene of Sakhalin can be included in *Mesodesma* is discussed under Mesodesmatidae. The Tertiary faunas of California are relatively well known and do not contain any *Mesodesma.* Their absence may reflect a paucity of sandy beach deposits. If *Califadesma* is ancestral to *Mesodesma,* the migration of this stock into southern waters might have been as early as Late Cretaceous but was not later than late Tertiary. The cool-water distribution of *Mesodesma* suggests that relatively cool periods during this time interval would have provided migration opportunities.

Donacids are unrecorded from Paleocene or between late Eocene and mid Pliocene in California, although another Recent sandy beach cohabiter, *Tivela,* is regularly represented in near-shore deposits beginning in the Oligocene. This lack of recorded donacids may result from the relatively small size of donacid shells and the uncom-

mon preservation of their sandy beach habitat which is usually sparsely fossiliferous when preserved and likely to be unexamined. Some *Aliodonax* shells preserve fine radial sculpture and structure, but none exhibits it to the extent usual among Holocene *Donax,* and none has denticulated valve margins. Possibly donacids were evolving the radial shell structure during the Late Cretaceous and Early Tertiary, but the absence of a better Early Tertiary record leaves the transition at present undocumented.

SYSTEMATIC PALEONTOLOGY

Order Veneroida H. & A. Adams, 1856

Superfamily TELLINACEA de Blainville, 1814

Family DONACIDAE Fleming, 1828

Although donacids appeared later than tellinids, POHLO (1967) suggested that the suspension-feeding donacids are unspecialized feeders and transitional to deposit-feeding tellinaceans. Donacids discussed in this paper have hinges with cardinal teeth that are not well separated from their lateral lamellae. These hinges are less advanced than those of tellinids of equivalent geologic age; thus, ancestors for tellinids must be sought elsewhere.

Genus *Notodonax* Feruglio, 1936

Type species by original designation *Donax annae-eugeniae* Feruglio, 1935.

The type species of *Notodonax* Feruglio, 1936, *Donax annae-eugeniae* from Patagonia, was described (FERUGLIO, 1935:90) from incomplete specimens interpreted to have two cardinals and an anterior lateral in each valve and two posterior laterals in the right valve and one in the left. The illustrations (FERUGLIO, 1936:pl 13, figs. 16–23) suggest that *Notodonax annae-eugeniae* bears considerable resemblance to *Notodonax* (*Aliodonax*) *hsui* sp. nov. and *N.* (*A.*) *bolsae* sp. nov. but has one more posterior lateral in each valve than is present in the California species. Additionally, the California species have one distinct cardinal in each valve, but the anterior cardinal is colaminal with the anterior lateral. Therefore the California species are placed in a new subgenus.

Aliodonax Saul, subgen. nov.

Type species *Notodonax* (*Aliodonax*) *hsui* Saul, sp. nov.

Diagnosis: *Aliodonax* is donaciform, solid, with a posterior angulation. Beaks are small, opisthogyral, and posterior to valve midline. Valve margin is smooth within. Ligament is in a deep groove behind short sturdy nymphs. Dentition consists of one posterior cardinal in each valve, 3b in right valve, 4b in left, and one posterior lateral in right valve. Anterior cardinals are not separated from anterior laterals, and in both valves the two form elongate colaminal anterior teeth, AIII-3a in right valve and AII-

2 in the left. Right valve has long anterior "socket" into which thick and beveled anterior dorsal margin of left valve fits. Pallial sinus is short and rounded with dorsal arm sloping ventrally.

Discussion: The colaminal state of the anterior cardinals and laterals suggests a less evolved stage of hinge development than is described for *Notodonax s.s.* and *Protodonax* Vokes, 1945. Whereas in *Protodonax* the left valve hinge formula is AII 2 4b PII, in *Aliodonax* it is AII-2 4b (see Figure 3 for hinge diagrams and formulae). No complete right-valve hinge of *Protodonax* has been described. The two California species comprising *Aliodonax* have fewer and shorter laterals (especially posterior laterals), and a larger, more robust nymph than do species of *Protodonax*. VOKES (1945) did not find radial sculpture in *Protodonax* species nor is its presence mentioned by FERUGLIO (1936) in describing *Notodonax*. Fine radial sculpture and structure is present in the surficial shell layer of the posterior quarter of valves of *N.* (*A.*) *hsui*. It has not been recognized in valves of *N.* (*A.*) *bolsae*, but the shells of *N.* (*A.*) *bolsae* are so completely recrystallized that such structure and sculpture might have been obliterated. Radial structure is present in a medial shell layer of Holocene donacids from the eastern Pacific Panamic province (KEEN, 1971:234).

The name *Aliodonax* is compounded of the Latin *alius* meaning "another" or "other," and *Donax,* a bivalve genus. *Donax* is of masculine gender.
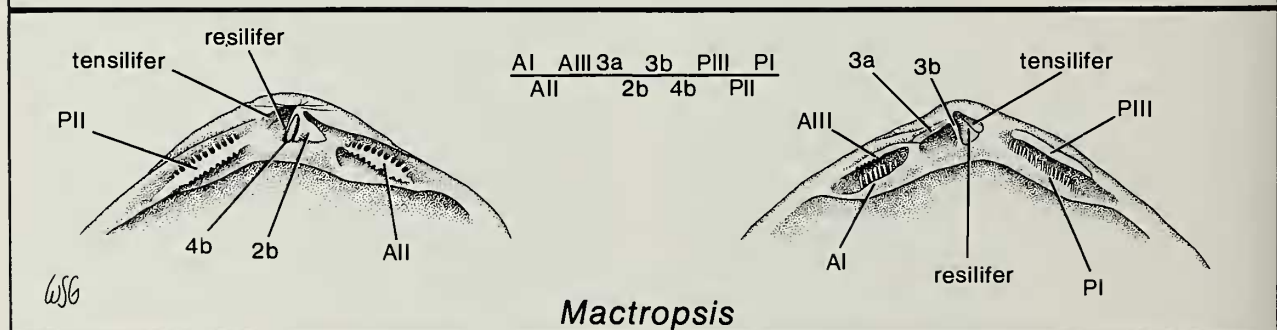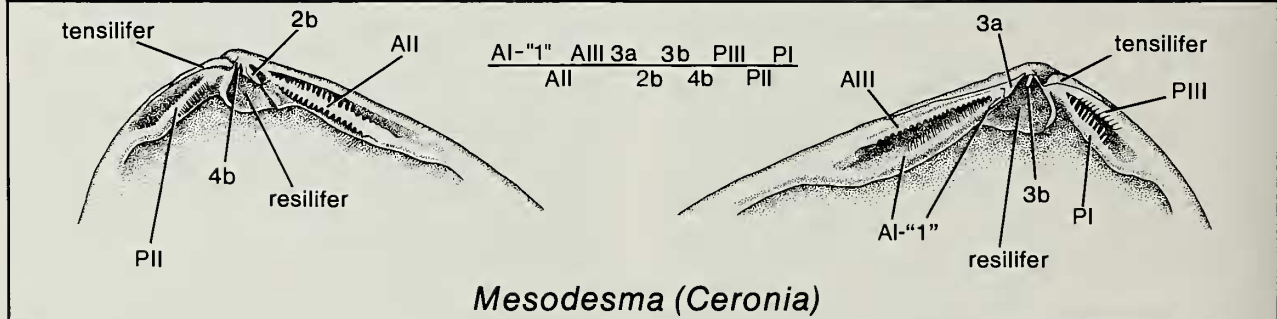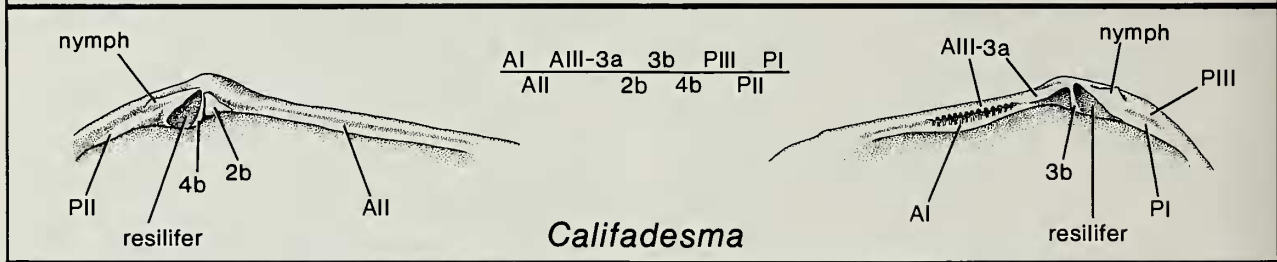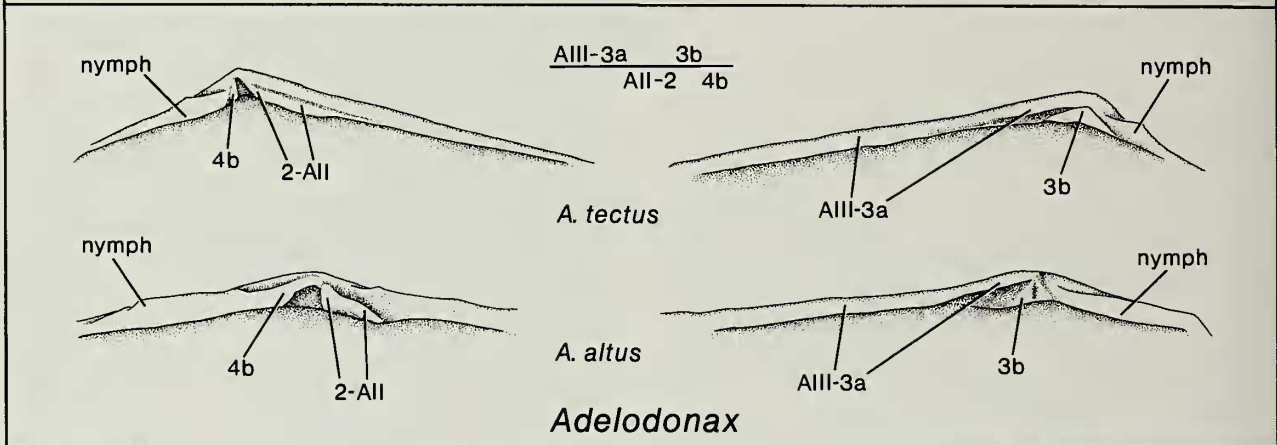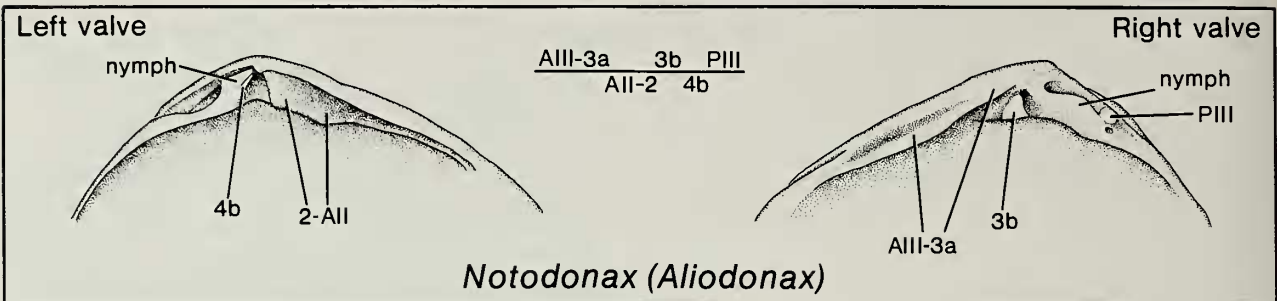
Notodonax (*Aliodonax*) *hsui* Saul, sp. nov.

(Figures 4–14)

Diagnosis: Elongate *Aliodonax* having the beak within the posterior third of the shell length. The hinge has, in the right valve aligned with the anterior hinge plate and valve margins, a long anterior colaminal tooth that is low adjacent to the beak and becomes high distally.

Description: Shell large for a donacid, thick. Valves elongate, compressed anteriorly, inflated and truncated posteriorly; anterodorsal margin nearly straight; anterior margin rounded, curving smoothly into ventral margin; ventral margin barely convex, angled abruptly into posterior margin; posterior margin nearly at right angle to ventral, rather straight, curving into very short posterodorsal margin; posterior angulation abrupt, parallel to and very near posterior margin. Beaks small, opisthogyral, very near posterior end; umbonal area blunt and broad. Lunule long, slightly depressed, bounded by low angulation. Exterior of valves with unevenly prominent growth lines and obscure radial ribbing on posterior quarter of shell.

Hinge with heavy, short nymph and deep ligament groove. Hinge of right valve with large, deltoid 3b vertically directed, immediately under beak; colaminal 3a-AIII very long, low and at valve margin dorsally, becoming high, bladelike, and aligned with hinge plate margin; long anterior "socket" for left valve anterior margin, dorsal to 3a-AIII; posterior lateral a low node just at base of ligament

Left valve   Right valve

$$\frac{\text{AIII-3a} \quad \text{3b} \quad \text{PIII}}{\text{AII-2} \quad \text{4b}}$$

nymph
4b
2-AII
AIII-3a
3b
nymph
PIII

Notodonax (Aliodonax)

nymph
4b
2-AII

$$\frac{\text{AIII-3a} \quad \text{3b}}{\text{AII-2} \quad \text{4b}}$$

AIII-3a
3b
nymph

A. tectus

nymph
4b
2-AII
AIII-3a
3b
nymph

A. altus

Adelodonax

nymph
PII
resilifer
4b
2b
AII

$$\frac{\text{AI} \quad \text{AIII-3a} \quad \text{3b} \quad \text{PIII} \quad \text{PI}}{\text{AII} \quad \text{2b} \quad \text{4b} \quad \text{PII}}$$

AIII-3a
nymph
PIII
AI
3b
resilifer
PI

Califadesma

tensilifer
2b
AII
PII
4b
resilifer

$$\frac{\text{AI-"1"} \quad \text{AIII} \quad \text{3a} \quad \text{3b} \quad \text{PIII} \quad \text{PI}}{\text{AII} \quad \text{2b} \quad \text{4b} \quad \text{PII}}$$

3a
AIII
tensilifer
PIII
AI-"1"
resilifer
3b
PI

Mesodesma (Ceronia)

tensilifer
resilifer
PII
4b
2b
AII

$$\frac{\text{AI} \quad \text{AIII} \quad \text{3a} \quad \text{3b} \quad \text{PIII} \quad \text{PI}}{\text{AII} \quad \text{2b} \quad \text{4b} \quad \text{PII}}$$

3a
3b
tensilifer
AIII
PIII
AI
resilifer
PI

Mactropsis

WSG

groove. Pallial sinus extending just beyond line dropped from beaks, rounded; dorsal arm sloping ventrally from posterior adductor muscle scar; ventral arm partially confluent with pallial line. Muscle scars nearly equal, rather round; anterior scar distant from beaks; posterior scar very near beaks. Interior valve margin smooth.

Holotype: LACMIP 7813.

Paratypes: LACMIP 7814 from CIT loc. 1016, Chico Creek; 7861 from UCLA loc. 3621, Chico Creek; 7815–7817 from UCLA loc. 3622, Chico Creek; 7818 from UCLA loc. 3628, Chico Creek, Paradise Quadrangle, Butte Co.; 7819 from UCLA loc. 4247, south side of Oak Run, Millville Quadrangle, Shasta Co., California.

Dimensions: Of holotype, length 54 mm, height 30.5 mm, inflation of single valve 11 mm, length beak to posterior 12 mm; of paratype LACMIP 7815, length 24 mm, height 12 mm, inflation of single valve 4.4 mm, length beak to posterior 8.3 mm; of paratype LACMIP 7816, length 21.4 mm, height 9 mm, inflation of single valve 3.4 mm, length beak to posterior 6.3 mm; of paratype LACMIP 7819, length 21.9 mm, height 11.1 mm, inflation of single valve 4.3 mm, length beak to posterior 6.8 mm.

Type locality: UCLA loc. 3621, Chico Creek, Paradise Quadrangle, Butte Co., California.

Distribution: Musty Buck Member of the Chico Formation, from 370 to 450 m above the base of the section on Chico Creek (UCLA locs. 3621, 3622, 3625, CIT loc. 1016), Butte Co.; Redding Formation on south side of Oak Run (UCLA loc. 4247), Millville Quadrangle, Shasta Co., California.

Age: Santonian.

Remarks: The holotype is a large right valve. Large valves are strongly truncate posteriorly, but the growth lines indicate that the shape changes ontogenetically, and small valves are less truncate posteriorly and relatively less produced anteriorly. The pallial sinus is described from one of these small individuals. No left valve is available. Small individuals resemble both *Califadesma elaphium* sp. nov. and *Adelodonax tectus* sp. nov. with which they co-occur. Anterodorsal and ventral margins of *Notodonax* (*A.*) *hsui* slope toward each other, and the valves wedge anteriorly more than do those of *Califadesma elaphium*; *N.* (*A.*) *hsui* lacks the double posterior angulation of *C. elaphium*. *Notodonax* (*A.*) *hsui* differs from the similarly shaped *A.*

tectus in having better developed hinge teeth, a shorter nymph, the ventral arm of the pallial sinus partially confluent with the pallial line, and radial riblets (Figure 7) on the posterior quarter of the valve.

The species is named for K. J. Hsu who assisted in measuring the Chico Creek section.

Notodonax (*Aliodonax*) *bolsae* Saul, sp. nov.

(Figures 16–21)

Diagnosis: Moderately elongate *Aliodonax* having beak more than a third of the shell length from the posterior margin. Hinge of right valve has a long anterior colaminal tooth, at an angle to the hinge plate and valve margins, that is relatively high adjacent to the beak.

Description: Shell large for a donacid; valves elongate, compressed anteriorly, inflated and truncated posteriorly; anterodorsal margin nearly straight; anterior margin rounded, curving smoothly into ventral margin; ventral margin broadly convex, angled abruptly into posterior margin; posterior margin at about 60° to ventral, rather straight, curving into very short posterodorsal margin; posterior angulation strong, parallel to and very near posterior margin. Beaks small, opisthogyral, near posterior third; umbonal area blunt and broad. Exterior of valves with unevenly prominent growth lines.

Hinge with heavy, short nymphs and deep ligament groove. Hinge of right valve with large, anteriorly slanted, deltoid 3b and long, thin, colaminal 3a-AIII; long, well developed anterior "socket" for margin of left valve; posterior lateral a low node just behind base of ligament groove. Hinge of left valve with posteriorly hooked, anteriorly directed, elongate 2-AII and short, lamellar, posteriorly directed 4b. Pallial sinus and muscle scars unknown. Interior valve margin smooth.

Holotype: LACMIP 7820.

Paratypes: LACMIP 7821–7824 from UCLA loc. 4347, near Bolsa Point, Pigeon Point Quadrangle, San Mateo Co., California.

Dimensions: Of holotype, somewhat crushed posteriorly, length 44.4 mm, height 27.5 mm, thickness 10 mm, distance of beak from posterior 14.3 mm; of paratype LACMIP 7821, length 37.4 mm, height 20.5 mm, thickness 6.4 mm, distance of beak from posterior 14.3 mm.

Type locality: UCLA loc. 4347, about 880 m north of

Figure 3

Diagrams of hinges and hinge formulae of supraspecific donacid and mesodesmatid taxa discussed in this paper. All hinges enlarged to approximately equal size. Both *Aliodonax* and *Adelodonax* have lucinoid-type hinges. These hinges are primitive in that cardinal tooth 2 is attached to lateral AII and cardinal 3a is attached to lateral AIII. *Califadesma* and *Mesodesma* have arcticoid-type hinges that are strongly modified by the submergence of the resilium and in *Mesodesma* by its forward rotation. In *Califadesma* the cardinal teeth, although crowded forward, are readily recognizable, but in *Mesodesma* the cardinals are vestigial and not easily seen without some magnification.

Bolsa Point, Pigeon Point Quadrangle, San Mateo Co., California.

Distribution: Known only from the type locality.

Age: Campanian.

Remarks: All five specimens of *Notodonax* (*A.*) *bolsae* are tectonically somewhat distorted and the shell material is recrystallized. *Notodonax* (*A.*) *bolsae* has a longer more sloping posterodorsal margin resulting in beaks that are more centrally positioned than in *N. hsui*.

The species is named for its occurrence at Bolsa Point, San Mateo Co., California.

Genus *Adelodonax* Saul, gen. nov.

Type species *Adelodonax tectus* Saul, sp. nov.

Diagnosis: Valves of *Adelodonax* are smooth except for growth lines, elongate, and moderately inflated. Low beaks are slightly opisthogyral and posterior to the middle. Ligament is behind a long nymph. Hinge of right valve has one triangular cardinal (3b); a socket anterior to the cardinal, and an elongate, colaminal anterior tooth (AIII-3a). Left valve has one elongate, colaminal anterior tooth (AII-2) ventral to a long socket, a shallow socket beneath beak, and usually a low cardinal (4b) posterior to the shallow socket. Anterior adductor muscle scar is well impressed for such a thin shell and subtriangular in shape; posterior adductor muscle scar is plumply ovoid in shape. Pallial sinus is of moderate depth. U-shaped, and distant from pallial line.

Discussion: *Adelodonax* is doubtfully placed in the family Donacidae. The hinge teeth are delicate and difficult to expose from the matrix. They are reminiscent of juvenile hinges or an early stage in the development of the lucinoid hinge. In their indistinctness they resemble those of Quenstedtiidae Cox, 1929b; *Adelodonax*, however, has a ligament groove behind an alate nymph but does not have a ligament pit. The hinge teeth are somewhat better defined than those of Quenstedtiidae and might be derived therefrom, but to evolve a ligament seated in a groove behind an alate nymph from a ligament in a pit requires considerable change both to the shell attachment area and the structure of the ligament. *Adelodonax* has anterior laterals but not the long anterior and posterior laterals of Sowerbyiidae Cox, 1929b; anterior laterals are usually absent in Tancrediidae Meek, 1864 (COX, 1929a). The nymph and ligament groove of *Adelodonax* are long for a donacid. The dorsal ends of the long colaminal teeth have not yet differentiated into cardinals, and *Adelodonax* differs from other Donacidae in having one rather than two cardinals in each valve and in lacking posterior laterals (see Figure 3 for hinge diagrams and formulae). The valves may gape slightly posteriorly.

COX (1929a) and CHAVAN (1950) suggested that Don-

acidae are derived from Tancrediidae. Three supraspecific tancrediid taxa—*Palaeomya* Zittel & Goubert, 1861, *Isotancredia* Chavan, 1950, and *Paratancredia* Chavan, 1950—resemble *Adelodonax* in shape, but differ from *Adelodonax* in having posterior laterals and lacking a pallial sinus. Both *Isotancredia* and *Paratancredia* resemble *Adelodonax* in having an anterior colaminal tooth (AIII-3a) in the right valve. *Eodonax* Cox, 1929a, and *Protodonax* possess characteristics considered to be intermediate between the two families (COX, 1929a; VOKES, 1945; CHAVAN, 1950) and the classification of each has oscillated between both families. *Adelodonax* also has characteristics that may be intermediate. The anterior colaminal teeth are suggestive of Tancrediidae, but an absence of posterior laterals suggests Donacidae. The hinge is more primitive than that of any other donacid and more primitive than that of most Tancrediidae, but the pallial sinus is deeper than that of tancrediids and suggests Donacidae.

Adelodonax bears a strong resemblance to *Ceroniola* Wilckens, 1904. Keen (*in* MOORE, 1969:N609) follows WILCKENS (1904) in considering this small, thin bivalve to be related to *Mesodesma,* and STINNESBECK (1986) has reaffirmed this classification. The left valve hinge of *Adelodonax* differs from that of *Ceroniola* in lacking posterior laterals; in *Adelodonax* the depression between AII-2 and 4b is here interpreted as a socket for 3b; whereas, for *Ceroniola,* Keen (*in* MOORE, 1969) and STINNESBECK (1986) have interpreted this as a resilifer. The most prominent tooth in the right valve hinge of *Adelodonax,* cardinal 3b, is shaped and positioned to fit this socket. Illustrations of *Ceroniola* suggest that this area beneath the beak is the damaged portion of the right valve; if so, a resilifer has not been clearly demonstrated to be present in *Ceroniola,* and it and *Adelodonax* may be confamilial.

Adelodonax also resembles *Amphichaena* Philippi, 1847, in shape but the hinge teeth of *Amphichaena* are concentrated closer to the beaks, and the hinge is more advanced with a hinge formula of AI-3a 3b in the right valve and AII-2 4b in the left valve.

The name *Adelodonax* is compounded from the Greek *adelos,* meaning "unseen, unknown, obscure," and *Donax,* a bivalve genus of masculine gender.

Adelodonax tectus Saul, sp. nov.

(Figures 14, 22–28)

Diagnosis: *Adelodonax* having the beak very near the posterior end and a moderate posterior angulation.

Description: Shell thin, small; valves elongate, compressed and produced anteriorly, moderately inflated and truncated posteriorly; anterodorsal margin rather straight, anterior margin bluntly rounded, ventral margin barely convex, posterior margin truncated. Beaks opisthogyral, situated very near posterior end. Lunule depressed, long
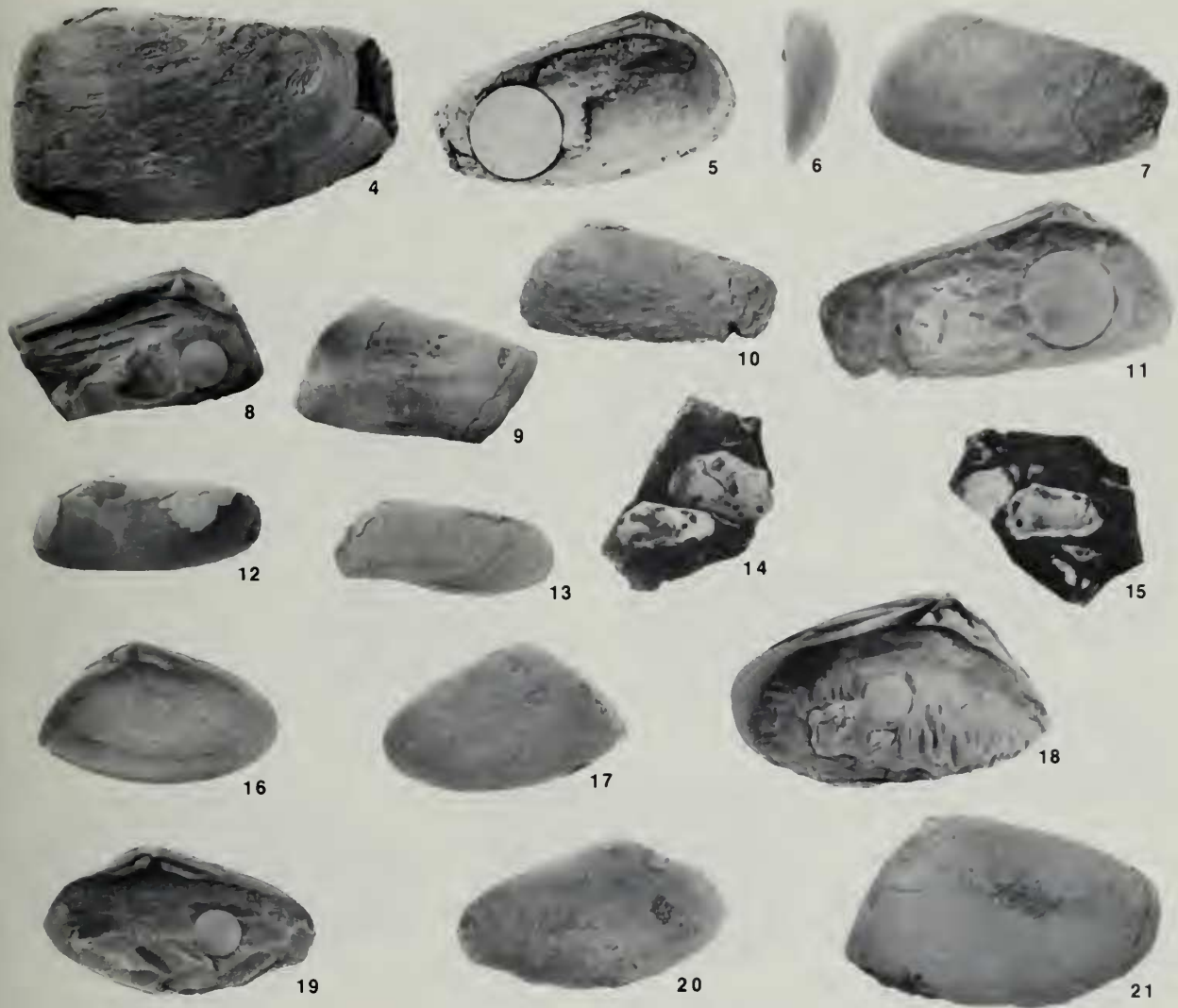
Explanation of Figures 4 to 21

Figures 4–13. *Notodonax* (*Aliodonax*) *hsui* sp. nov., right valve. Figure 4: LACMIP 7813 from UCLA loc. 3621, holotype, ×1. Figures 5–7: LACMIP 7819 from UCLA loc. 4247, paratype, ×2; Figure 5, hinge, teeth worn; Figure 6, posterior; Figure 7, fine radial ribbing on dorsal half. Figures 8, 9: LACMIP 7814 from CIT loc. 1014, paratype, ×1; Figure 8, hinge, nymph chipped; Figure 9, exterior. Figures 10, 11: LACMIP 7815 from UCLA loc. 3622, paratype; Figure 10, exterior, ×1.5; Figure 11, hinge, ×2. Figure 12: LACMIP 7816 from UCLA loc. 3622, paratype, ×1.5. Figure 13: LACMIP 7818 from UCLA loc. 3628, paratype, ×1.5.

Figures 14, 15. Two sides of sandstone fragment Chico Formation, Musty Buck Member, UCLA loc. 3622, ×1. Figure 14: *Notodonax* (*Aliodonax*) *hsui*, LACMIP 7817, and *Adelodonax tectus* sp. nov., LACMIP 7832. Figure 15: *Califadesma elaphium* sp. nov., LACMIP 7853.

Figures 16–21. *Notodonax* (*Aliodonax*) *bolsae* sp. nov., from UCLA loc. 4347. Figures 16, 17: LACMIP 7822, paratype, left valve, ×1; Figure 16, hinge; Figure 17, exterior. Figures 18, 21: LACMIP 7820, holotype, right valve slightly crushed posteriorly, ×1; Figure 18, hinge, nymph chipped; Figure 21, exterior. Figures 19, 20: LACMIP 7821, paratype, left valve, distorted longitudinally, ×1; Figure 19, hinge; Figure 20, exterior.

and very narrow; posterior angulation low. Exterior of valves polished, showing only growth lines.

Hinge with prominent nymph for ligament. Right valve with triangular, low rounded 3b with indistinct socket posterior to it and better defined socket anterior to it; colaminal AIII-3a very long, lamellar, extending from im-

mediately in front of beak for nearly one-third length of anterodorsal margin. Left valve with elongate colaminal AII-2 and short obscure cardinal 4b on either side of the triangular, shallow, round-bottomed socket for 3b. Pallial line distant from valve margin anteriorly, becoming moderately close to margin posteriorly; pallial sinus U-shaped,

Explanation of Figures 22 to 41

Figures 22–28. *Adelodonax tectus* sp. nov., from UCLA 3622. Figure 22: LACMIP 7825, holotype, left valve, ×1. Figure 23: LACMIP 7827, paratype, hinge left valve, ×3. Figure 24: LACMIP 7826, paratype, hinge left valve, ×3. Figure 25: LAC-MIP 7829, paratype, right valve, ×1. Figure 26: LACMIP 7828, paratype, right valve, pallial sinus, ×2. Figure 27: LACMIP 7830, paratype, hinge right valve, ×2. Figure 28: LACMIP 7831, paratype, hinge right valve, ×3.

Figures 29–41. *Adelodonax altus* (Gabb, 1864). Figure 29: ANSP 4557 from Martinez, Contra Costa Co., Calif., lectotype, ×2. Photo by Takeo Susuki. Figure 30: ANSP 71880 from Martinez, Contra Costa Co., Calif., paralectotype, left valve showing trace of pallial line, ×2. Photo by Takeo Susuki. Figures 31, 38:

LACMIP 7843 from UCLA 6489, hypotype, right valve; Figure 31, exterior, ×1; Figure 38, hinge, ×2. Figure 32: LACMIP 7841 from UCLA 3960, hypotype, hinge left valve, ×2. Figure 33: LACMIP 7840 from UCLA loc. 3958, hypotype, hinge right valve, ×2. Figure 34: LACMIP 7842 from UCLA loc. 3960, hypotype, "butterflied" valves, ×1.5. Figure 35: LACMIP 7862 from UCLA loc. 6489, hypotype, hinge left valve, ×2. Figures 36, 40: LACMIP 7837 from LACMIP 28629, hypotype, interior left valve, ×2; Figure 36, rock mold; Figure 40, latex pull. Figures 37, 41: LACMIP 7839 from LACMIP loc. 28629, hypotype, hinge right valve, ×2; Figure 37, rock mold; Figure 41, latex pull. Figure 39: LACMIP 7838 from LACMIP loc. 28629, hypotype, interior of left valve, latex pull, ×2.

horizontal, extending to point just anterior to beaks. Muscle scars nearly equal, round, usually well impressed, posterior scar very near beaks, anterior scar distant.

Holotype: LACMIP 7825.

Paratypes: LACMIP 7826–7835 from UCLA loc. 3622 and LACMIP 7836 from UCLA loc. 3623.

Dimensions: LACMIP 7825, length 25 mm, height 10 mm, inflation of single valve 3.7 mm, beak to posterior 7 mm; LACMIP 7829, right valve length 18 mm, height 7.8 mm, inflation of single valve 2 mm, beak to posterior 6 mm.

Type locality: UCLA loc. 3622, Chico Creek, Paradise Quadrangle, Butte Co., California.

Distribution: 440 m (1320 feet) to 560 m (1740 feet) above the base of the Chico Creek section in the Musty Buck Member of the Chico Formation (UCLA locs. 3622–3624, 3627, 3633), Butte Co., California.

Age: Santonian.

Remarks: *Adelodonax tectus* has the beaks more posteriorly placed, and the valves shorter than those of *A. altus*. *Adelodonax tectus* is less elongate than *Ceroniola australis* and has a relatively longer nymph.

At its type locality on Chico Creek, *Adelodonax tectus* occurs in abundance with *Notodonax* (*Aliodonax*) *hsui* and *Califadesma elaphium*; all three are of similar shape. Large specimens of *N.* (*A.*) *hsui* are readily distinguished from *A. tectus* by their abrupt posterior angulation, but small individuals have a less abrupt angulation. They can be distinguished from *A. tectus* by their better developed hinge teeth, presence of radial striations on the posterior quarter of the shell, and broader pallial sinus, the lower limb of which is partially confluent with the pallial line. *Califadesma elaphium* is most readily distinguished from *Adelodonax tectus* by the double angulation of the posterior slope on the former.

The specific name is from the Greek *tecktos,* meaning "soluble," and refers to the leached condition of most specimens from the type locality.

Adelodonax altus (Gabb, 1864)

(Figures 29–41)

Pharella alta GABB, 1864:147, pl. 22, fig. 118; Stewart, 1930: 293, pl. 5, fig. 11.

Diagnosis: Elongate *Adelodonax* with the beak at the posterior third and having a slight posterior truncation.

Description: Shell thin, small; valves elongate, compressed and produced anteriorly, moderately inflated and slightly truncated posteriorly; anterodorsal margin rather straight, anterior margin bluntly rounded, ventral margin nearly straight, posterior margin truncated. Beaks opisthogyral, situated at posterior third of the valve. Lunule depressed, long and very narrow; posterior angulation very low. Exterior of valves polished, showing only growth lines.

Hinge with prominent nymph for ligament. Right valve with triangular, low rounded 3b with indistinct socket posterior to it and better defined socket anterior to it; colaminal AIII-3a very long, lamellar, extending from immediately in front of beak for nearly one-third length of anterodorsal margin. Left valve with AII-2 long, lamellar, and extending anterior to long lateral socket; 4b a slightly raised welt on hinge plate posterior to triangular, shallow, round-bottomed socket. Pallial line distant from valve margin anteriorly, becoming moderately close to margin posteriorly; pallial sinus U-shaped, horizontal, extending to point just anterior to beaks. Muscle scars of nearly equal size; posterior scar very near beaks; anterior scar distant, moderately well impressed, acutely subtrigonal.

Lectotype: ANSP 4557, **herein designated.** STEWART (1930:293) could not recognize the specimen figured by GABB (1864). He suggested that if no better specimen from Gabb's original material was found, the specimen STEWART (1930:pl. 5, fig. 11) figured might be designated lectotype. That specimen has been missing since 1960 (Elana Benamy, *in litt.*, 20 Nov. 1987). Two specimens remain of Gabb's original material: an incomplete left valve similar in size to the specimen figured by Stewart and a "butterflied" pair of valves that are one-third smaller. The "butterflied" pair of valves, although small, provides a better indication of valve shape and is chosen as lectotype (Figure 29).

Paralectotype: ANSP 71880 (Figure 30).

Hypotypes: LACMIP 7837–7839 from LACMIP loc. 28629, LACMIP 7840 from UCLA loc. 3958, LACMIP 7841–7842 from UCLA loc. 3960, LACMIP 7843 from UCLA 6489.

Dimensions: Lectotype ANSP 4557 right valve, length 12 mm, height 6.5 mm, beak to posterior 4.8 mm; hypotype LACMIP 7842, length 14 mm, height 6.4 mm, beak to posterior 5.8 mm.

Type locality: Near Martinez, Contra Costa Co., California (GABB, 1864).

Distribution: Great Valley Series near Martinez and Deer Valley, Contra Costa Co.; Garzas Member of the Moreno Formation near Garzas (LACMIP loc. 8148) and Orestimba creeks (UCLA locs. 6359, 6360, 6489), Merced and Stanislaus cos., California. Poorly preserved specimens from the Cabrillo Formation on Mt. Soledad (LACMIP loc. 28629), San Diego Co. (identified as "*Pharella alta*" in KENNEDY, 1975:15). Rosario Formation on the north side of Punta Banda (UCLA loc. 7137), Baja California, Mexico.

Age: Maastrichtian. GABB (1864) indicated that *Pharella alta* was from the "Martinez Group," but it has not subsequently been recovered from deposits of Paleocene age near Martinez. STEWART (1930:293) recognized that

the rock type and preservation are typical of the Late Cretaceous Great Valley Series from the vicinity of Martinez, Contra Costa Co., California, and at several Contra Costa County localities (UCLA locs. 3958, 3959, 3960, 3314, and 4671), it has been found in association with species indicative of late Maastrichtian age. The Cabrillo Formation on Mt. Soledad, which yields abundant *Adelodonax altus,* is not continuous with other outcrops of the Cabrillo Formation (KENNEDY, 1975), and no other age diagnostic fossils have been found there. The specimen from the Rosario Formation on Punta Banda, Baja California, occurs with other mollusks of early Maastrichtian age.

Remarks: STEWART (1930:293) suspected that this species was not a *Pharella,* but did not reassign it. He mistook the anterior for the posterior, indicating that the shell is "produced posteriorly" and that the beaks are prosogyral and anterior to the valve middle. The position of the pallial sinus shows "*Pharella*" *alta* Gabb, 1864, to be anteriorly produced.

Although GABB (1864) did not mention any similarity between *Pharella alta* and *Cultellus australis* Gabb, 1860, described from Chile, the two are similar in shape. *Cultellus australis* has a somewhat more anteriorly elongate shell than *P. alta.* The Chilean species was moved to *Solen*[?] (*Cultellus*) by PHILIPPI (1887), and designated the type species of the new genus *Ceroniola* by WILCKENS (1904: 249, pl. XX, figs. 11a, b, 12, 13). The left hinge of *Ceroniola australis* (Gabb, 1860) (WILCKENS, 1904:pl. XX, fig. 11a; STINNESBECK, 1986: pl. 4, fig. 3) resembles that of *Adelodonax altus* except for the presence of posterior laterals in the former. WILCKENS (1904) lacked a complete right valve hinge of *Ceroniola australis,* and STINNESBECK's right valve is also incomplete (1986:pl. 4, fig. 4). STINNESBECK appears to have inadvertently flipped the negatives so that the right and left hinges of *Ceroniola australis* are printed as mirror images (1986:pl. 4, figs. 3, 4). WILCKENS (1904: 249, pl. XX, fig. 13) described a long anterior and a short posterior groove. He considered the posterior groove to be too distant from the valve margin to be a ligament groove. The common preservation of specimens of *Adelodonax* in the butterfly position with the nymphs adjacent suggests that the ligament attached the valves here and that the similar groove and nymph structure of *Ceroniola* may have been the site of ligament attachment. The age of *Ceroniola australis* (Gabb), which is from the Quiriquina Formation (WILCKENS, 1904:205; STINNESBECK, 1986) is erroneously given as "U. Tertiary" by Keen (in MOORE, 1969:N609). PHILIPPI (1887) referred the Quiriquina beds to the Unter Tertiaren, but the Quiriquina beds were regarded as Cretaceous by WILCKENS (1904) and are presently considered to be of Maastrichtian age (STINNESBECK, 1986; RICCARDI, 1987:table III). Thus the type species, *Ceroniola australis* is from the same stage as *Adelodonax altus* (Gabb).

Specimens of *Adelodonax altus* are usually poorly preserved, in part because the shells are thin and in part because the sandstone matrix in which they occur is porous and subjects them to leaching. The best specimens are from the Great Valley Series near Martinez and Deer Valley, Contra Costa Co. The specimens from the Cabrillo Formation on Mt. Soledad, San Diego Co., are mainly molds in a coarse, mica-rich sandstone matrix. Despite the coarse-grained matrix, latex pulls provide hinge details (Figures 36, 37, 39–41). Well preserved specimens are also present in hard sandstone of the Rosario Formation on the north side of Punta Banda, Baja California, Mexico (UCLA loc. 7137), associated with a diverse bivalve and gastropod fauna (SAUL, 1970) that is probably of early Maastrichtian age.

Superfamily MACTRACEA Lamarck, 1809

DALL (1898:910) placed the genus *Mactropsis* Conrad, 1854, in the Mesodesmatidae, apparently because of its thick shell, as he stated (1898:907–908) that fossil species of Mesodesmatidae might be distinguished from the mactrids by their excessive solidity and thickness of their valves rather than by any clearly marked differential characters. He did not, however, exclude certain other thick shelled forms from the Mactridae, e.g., *Pseudocardium* Gabb, 1866. Keen (in MOORE, 1969:N610) and BEU (1971) retained *Mactropsis* in the Mesodesmatidae, but PALMER & BRANN (1965:190) included it in the Mactridae, a placement with which I concur.

DALL (1895:910–911) considered *Mactropsis* an ancestral mesodesmatid, and he stressed the more primitive features of its hinge with respect to the hinge of Recent *Mesodesma.* In addition to the features described by Dall, *Mactropsis* has left valve laterals AII and PII that are strongly striated on both sides and right valve laterals that are strongly striated on one face, AI and PI on their dorsal face and AIII and PIII on their ventral face. These laterals resemble those of *Spisula.* Anterior lateral AI is not bimodal and shows no inclination toward the formation of an incipient cardinal 1 (Figure 3). The tensilifer and resilifer, which are not separated by a shelly partition, are of equal length, but the resilifer is approximately three times as wide as the tensilifer. The tensilifer is on the inner slope of the valve margin but exteriorly exposed in a narrow wedge just behind the beak. Figures 43 and 44 are of the hinge of the type species of *Mactropsis, Erycina aequorea* Conrad, 1833 (by subsequent designation, DALL, 1895).

In Recent species of *Mesodesma* the tensilifer is in a more external position than is that of *Mactropsis.* The tensilifer of *Mesodesma donacium* is a wide-based triangle with the dorsal side external and the anterior side internal and set off from the resilifer by the steeply depressed posterior side of the resilifer (Figures 50, 51). In *Mesodesma* (*Ceronia*) *arctatum* the tensilifer is smaller relative to the resilifer and set off from the resilifer by the overhanging edge of the deeply depressed posterior side of the resilifer (Figures 45, 46). In addition, *Mesodesma donacium* has
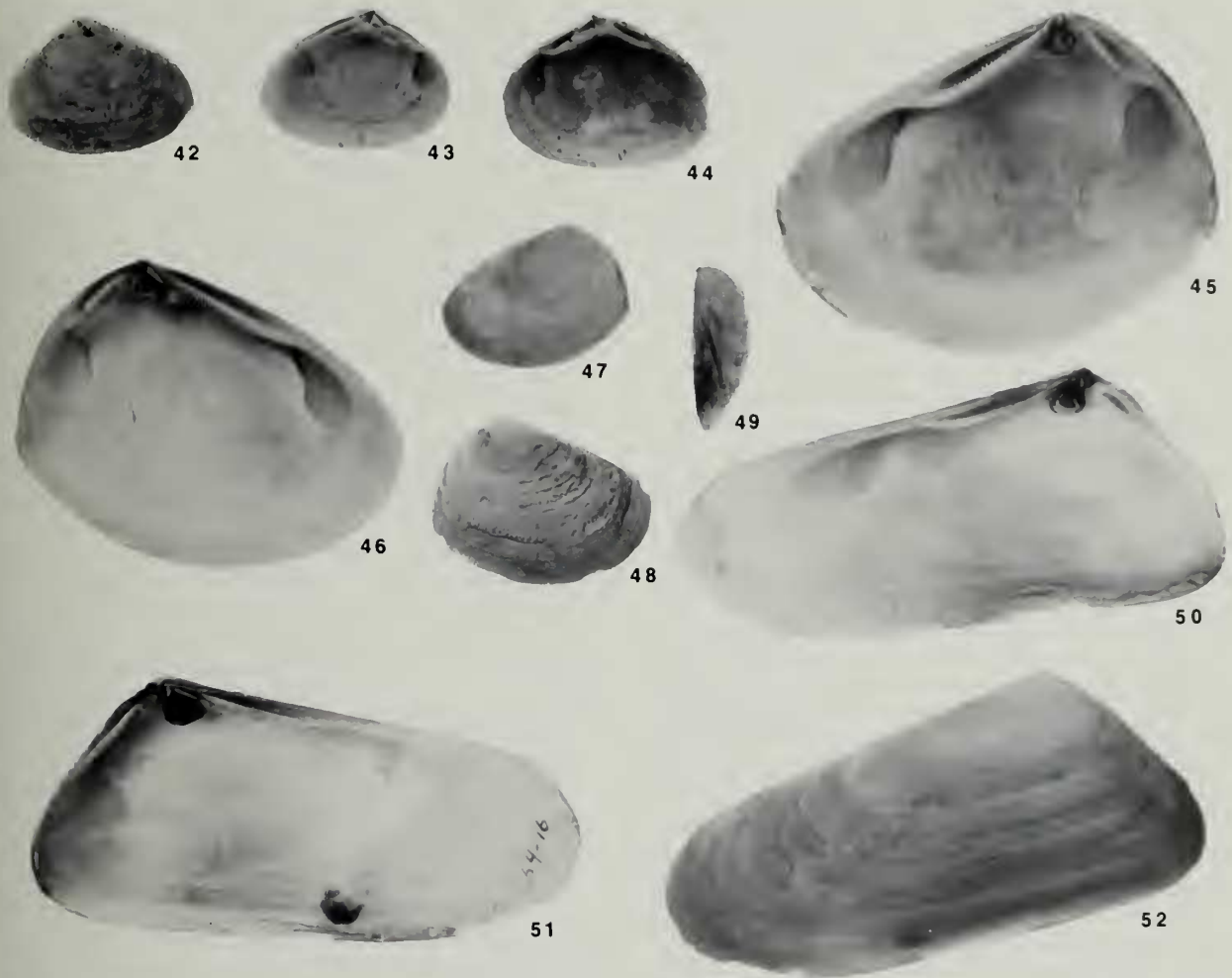
Explanation of Figures 42 to 52

Figures 42–44. *Mactropsis aequorea* (Conrad, 1833) from LACMIP loc. 5659, hypotypes. Figures 42, 43: LACMIP 7860, left valve, ×2; Figure 42, exterior; Figure 43, interior (see Figure 3 for labeling of teeth). Figure 44: LACMIP 7859, interior right valve, ×3 (see Figure 3 for labeling of teeth).

Figures 45–49. *Mesodesma (Ceronia) arctatum* (Conrad, 1830) from Hampton Harbor, New Hampshire, hypotypes. Figures 45, 48, 49: LACM 104120, right valve; Figure 45, interior, ×2 (see Figure 3 for labeling of teeth); Figure 48, exterior, ×1;

Figure 49, posterior, ×1. Figures 46, 47: LACM 104121, left valve; Figure 46, interior, ×2 (see Figure 3 for labeling of teeth); Figure 47, exterior, ×1.

Figures 50–52. *Mesodesma donacium* (Lamarck, 1818) from Iquique, Chile, hypotypes, ×1. Figure 50: LACM 64-16.1, right valve interior (see Figure 3 for labeling of teeth). Figures 51, 52: LACM 64-16.2, left valve; Figure 51, interior (see Figure 3 for labeling of teeth); Figure 52, exterior.

bimodal anterior lateral teeth AII and AI that exhibit a tendency to form incipient cardinals 2a and 1.

Califadesma gen. nov. provides a more likely progenitor for the hinge of *Mesodesma* than does that of *Mactropsis*. The laterals of *Califadesma* are already bimodal, as are those of *Mesodesma* but not those of *Mactropsis*. *Califadesma* has a relatively larger resilifer that extends to the hinge plate margin and the tensilium was behind nymphs. The seat of the tensilium of *Mactropsis* is more internal than that of either *Califadesma* or *Mesodesma* and, although it might have migrated inward from a similar ancestral position, it would have had to remigrate to a more

external position were *Mactropsis* ancestral to *Mesodesma*. Inward migration of tensilium and resilium is characteristic of mactrids (SAUL, 1973), and the tensilifer position of *Mesodesma* can be derived from that of *Califadesma* by inward repositioning that includes loss of the nymph. The overall shape of *Mactropsis* is trigonal with the beaks located anterior to the midpoint (Figure 42) rather than donaciform with posteriorly placed beaks as are *Califadesma* and *Mesodesma*.

DALL (1898:907) noted that no shell characters unequivocally differentiate the Mesodesmatidae from the Mactridae, but *Califadesma* is sufficiently similar to *Meso-*

desma to be a mesodesmatid. *Mactropsis* falls not between *Califadesma* and *Mesodesma* in morphologic features, as its age might suggest, but is more similar in shape and hinge features to typical *Spisula* than to *Mesodesma*. The more trigonal mesodesmatids, such as *Paphies* Lesson, 1831, have smooth rather than the striated laterals of *Mactropsis*. As there are a number of relatively thick shelled mactrids including *Spisula solida* (Linnaeus, 1758), the thick shell of *Mactropsis* provides insufficient reason for placing this genus in the Mesodesmatidae.

Myadesma Clark, 1922, comprises four Pacific Slope species of Eocene to Miocene age: *M. eocenica* Clark, 1938; *M. howei* Clark, 1922 (Figures 85, 86); *M. dalli* Clark, 1922, type species by original designation (Figures 79–84); and *M. pacifica* (Hall & Ambrose, 1916), originally described as a *Mesodesma* (Figure 78). *Myadesma* has been included in Mesodesmatidae (Keen *in* MOORE, 1969) or in Myadesmatidae (CLARK, 1922; BEU, 1971). Myadesmatidae has been considered related to Mesodesmatidae of the Veneroida (BEU, 1971), Myidae of the Myoida (CLARK, 1922; HICKMAN, 1969), or Periplomatidae of the Pholadomyoida (CLARK, 1922). *Myadesma* resembles *Mesodesma* in its cuniform shape with the beaks near the posterior end, in having a well-marked, shallow pallial sinus (Figure 78), and in having anteriorly directed resilifers. The resilifers differ greatly from those of *Mesodesma* in that the resilifer of the left valve protrudes beyond the plane of the commissure (Figures 79, 81–84, 86) and that of the right valve is correspondingly sunken and lies against the valve (Figures 82, 83). The shape and position of the resilifers were seen by CLARK (1922) as similar to those of Myidae. Additionally, within the resilifer of the left valve, CLARK (1922) recognized a lithodesma that indicated to him a close relationship to Periplomatidae, and he suggested that Myidae should be included among anomalodesmaceans because of these similarities. Preservation of the type material is such that it is difficult to determine whether or not the lithodesma is in part fused to the dorsal side of the resilifer in the left valve; CLARK (1922) said cemented. BEU (1971) indicated that it is fused to the resilifer of the left valve (Beu says "right valve," but he consistently uses right for left in his discussion of *Myadesma*). Matrix fills a narrow space between the resilifer and the lithodesma, but there is no well-demarked boundary between the posterodorsal half of the lithodesma and the ridge bounding the resilifer on its dorsal side. The hinge has been well described by CLARK (1922); its structures do not resemble those of mactraceans. Not mentioned in any description is the consistent foramen in the beak of the right valve (Figures 82, 83). Similar wear holes are present in the pholadomyoid families Myochamidae, Periplomatidae, and Thraciidae. Such holes are not present in mactraceans or myaceans. I concur with CLARK (1922) and BEU (1971) in placing this genus in the family Myadesmatidae Clark, 1922, and assign the family to the order Pholadomyoida Newell, 1965, and the superfamily Pandoracea Rafinesque, 1815.

Family MESODESMATIDAE Gray, 1840

The shells of the Mesodesmatidae are said to differ from those of the Mactridae in being disproportionately heavy (Keen *in* MOORE, 1969), but several genera with heavy shells are included in the Mactridae (*e.g., Spisula, Pseudocardium*), and some species of *Mesodesma* (*e.g., M. mactroides*) do not have a heavy shell. The siphons differ in the two families: those of Mesodesmatidae are naked and nearly or completely separated whereas in the Mactridae the siphons are united to their tips. As in the Mactridae, mesodesmatid hinges are arcticoid. KALISHEVICH (1967) incorrectly states that the resilifer of Mesodesmatidae is situated between the cardinal teeth, before cardinal 4b of the left valve. The resilifer of Mesodesmatidae is, however, placed as in Mactridae and is behind all cardinal teeth (see Figures 3, 45, 46, 50, 51) in both valves. In both Mactridae and Mesodesmatidae the cardinals are commonly crowded by the progressive enlargement and forward migration of the resilifer (SAUL, 1973). The resilifer has rotated far forward in such mesodesmatid species as *Mesodesma donacium* and *M. (Ceronia) arctatum*, and the insignificant, fragile cardinal teeth are both readily overlooked and easily broken off, but in both valves all cardinals are on the anterior side of the resilifer. Typical mesodesmatids with striated laterals are compressed, cuneiform, and only moderately heavy. In the group with smooth laterals, which includes *Paphies,* the shell is more or less compressed, more commonly trigonal than cuneiform, and usually heavy.

The *Treatise on Invertebrate Paleontology* does not list Mesodesmatidae as being present in the Cretaceous, although *Ceroniola* Wilckens, 1904, is included by Keen (*in* MOORE, 1969:N609) in this family. *Ceroniola* does not have mactroid hinge teeth. If it has a resilifer and is not related to *Adelodonax,* it may belong in the Quenstedtiidae.

Typical *Mesodesma* Deshayes, 1832, ranges from Pliocene to Recent (HERM, 1969); its subgenus *Ceronia* Gray, 1853, is known from Miocene to Recent (BEU & ROOIJ-SCHUILING, 1982). *Donacilla (Mesodesma) sakhalinensis* Kalishevich, 1967, of late Eocene age differs from *Mesodesma* in lacking striations on its laterals and a posterior lateral in the left valve. If KALISHEVICH (1967:fig 2c) is correct and cardinal 4b is on the posterior side of the resilifer, *D. (M.) sakhalinensis* is not a mesodesmatid. Its affinities cannot be determined from the published figures.

Genus *Califadesma* Saul, gen. nov.

Type species *Califadesma elafium* Saul, sp. nov.

Diagnosis: A mesodesmatid with the resilifer posteriorly slanted and the two cardinal teeth on the hinge plate. Posteriorly the shell has a double siphonal fold.

Description: *Donax*-shaped bivalves of small size with sturdy shells, externally smooth except for fine growth lines. Valves elongate and compressed anteriorly, truncated

and inflated posteriorly having a double siphonal fold. Beaks low, very near posterior end. Hinge with posteriorly directed resilifer and flange-like nymph for the ligament; two cardinal teeth in each valve. Right valve with two thin lamellar cardinals 3a, 3b on either side of large socket, anterior to the resilifer; well-developed, elongate, dorsally striate anterior lateral AI and weaker, ventrally striate AIII very near shell margin; two short posterior laterals. Left valve with deltoid anterior cardinal 2b and very thin posterior cardinal 4b; anterior lateral well developed, striate dorsally and ventrally, very elongate; posterior lateral short, striate dorsally and ventrally. Pallial sinus a wide but shallow embayment.

Remarks: *Califadesma* differs from *Mesodesma* in having the resilifer posteriorly slanted and the cardinals upon the hinge plate. In *Mesodesma* the resilifer has moved to a more medial position and crowded the cardinals up off of the hinge plate onto a thin shelf overhanging the dorsal end of the resilifer (Figures 45, 46, 50, 51). The hinge of *Califadesma*, with cardinals 3a, 3b, deltoid 2b, and 4b on the hinge plate, is more clearly mactroid (see Figure 3 for hinge diagrams) than is that of *Mesodesma*. SAUL (1988) erroneously reported that the laterals of these genera are striate only on the dorsal side, but AII and PII are finely striate on the ventral as well as the dorsal side, and AIII and PIII are finely striate on the ventral side in both *Mesodesma* and *Califadesma*.

The posterior of *Califadesma* is clearly marked by a double siphonal fold, the ridges of which are more angulate on the right valve and more rounded on the left valve. Possibly the double siphonal fold in these shells is a reflection of the separate siphons.

Three species are here assigned to the genus *Califadesma*: *C. aspris* sp. nov., *C. elaphium* sp. nov., and *C. tuscanum* sp. nov. All are from Upper Cretaceous deposits of northern California. The geologically oldest of these species, *C. aspris*, is least cuneate and most mactriform.

The generic name is compounded of *Calif* for California and the Greek *desma,* meaning "band, bundle," from *Mesodesma* to which it is apparently related and perhaps antecedant. A generic name ending in *desma* is of neuter gender.

Califadesma aspris Saul, sp. nov.

(Figures 53–61)

Diagnosis: Relatively high, inflated *Califadesma* having abrupt posterior angulations and the ventral margin of the left valve overhanging that of the right valve.

Description: Shell small, moderately thick, broadly wedge-shaped. Valves compressed anteriorly, truncated and inflated posteriorly; posterior with strong double angulation; more anterior angulations sharper and stronger, especially in right valve; left valve noticeably more inflated than right valve. Dorsal margin straight; anterior margin squarely rounded; ventral margin convex, especially medially; pos-

terior margin obtusely rounded and notched by sulcus between posterior two angulations. Beaks low, opisthogyral, very near posterior end. Lunule long, narrow, and slightly depressed.

Hinge with short, but well-developed flange-like nymph for external ligament and posteriorly directed resilifer immediately beneath beaks. Right valve with 3a and 3b very thin and lamellar, 3a scarcely detached from hinge margin and contiguous with long, thin, ventrally striate AIII; AI elongate; PI and PIII dorsally striate, short. Left valve with triangular 2b and very thin lamellar 4a adjacent to resilifer; AII bimodal, very long, lamellar, and striated; PII short, striated. Pallial line rather distant from valve margin; pallial sinus a wide but shallow indentation extending from posterior muscle scar to point ventrally below the beaks. Muscle scars subequal; posterior muscle scar round; anterior muscle scar elongate.

Holotype: LACMIP 7844, a large left valve.

Paratypes: LACMIP 7845 right valve from UCLA loc. 4104; 7846, a small right valve from CIT loc. 1893; 7847 medium left valve from CIT loc. 1893.

Dimensions: Of holotype LACMIP 7844 length 26.3 mm, height 18.8 mm, inflation of single valve 8.6 mm, beak 5.5 mm from posterior; paratype LACMIP 7845 length 23.8 mm, height 14.8 mm, inflation of single valve 4.9 mm, beak 4.6 mm from posterior; paratype LACMIP 7846 length 14.4 mm, height 9 mm, inflation of single valve 4 mm, beak 2.3 mm from posterior.

Type locality: LACMIP loc. 8133 (=UCLA loc. 4104, CIT loc. 1034, CIT loc. 1893), Oak Run, Millville Quadrangle, Shasta Co., California.

Distribution: Known only from the type locality.

Age: Coniacian, occurs with *Perissitys cretacea* (Cooper, 1896) and *Christitys delta* Popenoe & Saul, 1987.

Remarks: *Califadesma aspris* has the relatively highest, least elongate shell among donaciform bivalves discussed in this paper, and its ventral margin is the most convexly curved. The left valve is not only more inflated than the right valve, but the curved ventral margin of the left valve and its greater height to length ratio suggest that the ventral margin of the right valve fits within that of the left valve. Bilateral asymmetry may afford resistance to strong compressive forces during valve adduction and during attacks by shell-crushing predators (VERMEIJ, 1987:297). The loss of this characteristic between *C. aspris* and *C. elaphium* suggests that improved burrowing speed gained from a more streamlined, donaciform shape might have resulted in more escapes than did defensive armor, and thus have been of greater adaptive advantage.

Compared to *Califadesma elaphium* and *C. tuscanum*, *C. aspris* has the most abrupt posterior angulations; these angulations diverge at the smallest angle, and the posterior margin is most noticeably sinused between the angulations.
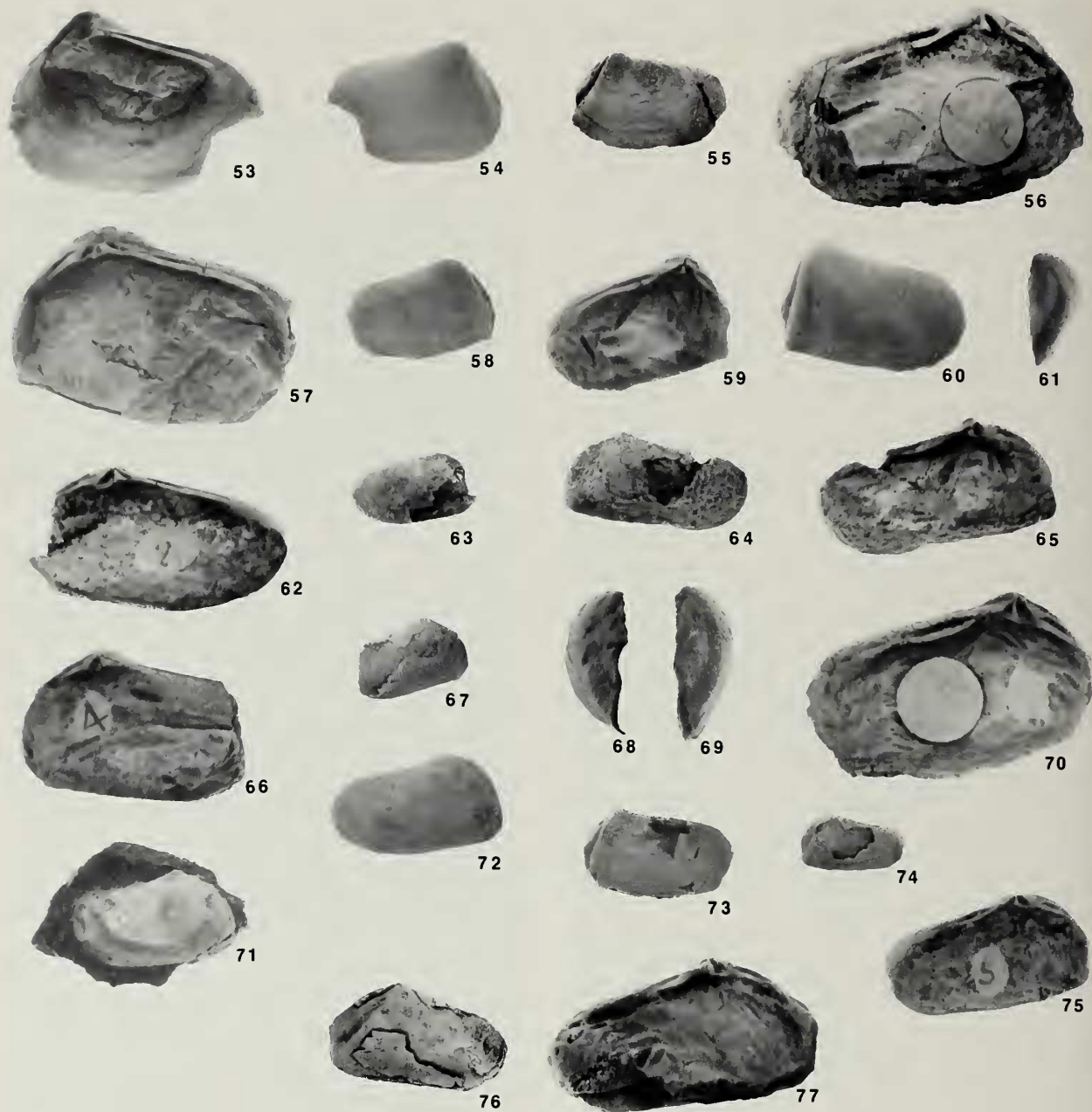
Explanation of Figures 53 to 77

Figures 53–61. *Califadesma aspris* sp. nov. Figures 53, 54: LACMIP 7844 from LACMIP loc. 8133, holotype, left valve; Figure 53, interior, posterior valve margin broken, ×1.5; Figure 54, exterior, ×1. Figures 55, 56: LACMIP 7845 from UCLA loc. 4101, paratype, right valve; Figure 55, exterior, ×1; Figure 56, interior, ×2. Figures 57, 58: LACMIP 7847 from LACMIP loc. 8133, paratype, left valve; Figure 57, interior, tip of beak broken off, ×2; Figure 58, exterior, ×1. Figures 59–61: LACMIP 7846 from LACMIP loc. 8133, paratype, right valve, ×2; Figure 59, interior; Figure 60, exterior; Figure 61, posterior.

Figures 62–75. *Califadesma elaphium* sp. nov. Figures 62, 63: LACMIP 7849 from UCLA loc. 3622, paratype, left valve, posterior end broken off; Figure 62, interior, ×2; Figure 63, exterior, ×1. Figures 64, 65: LACMIP 7848 from UCLA loc. 3622, holotype, right valve; Figure 64, exterior, ×1.5; Figure 65, in-

terior, ×2. Figures 66–68: LACMIP 7851 from UCLA loc. 3622, paratype, left valve, anterior end broken off; Figure 66, interior, ×2; Figure 67, exterior, ×1; Figure 68, posterior, ×2. Figures 69, 70, 73: LACMIP 7854 from UCLA loc. 4247, paratype, right valve; Figure 69, posterior, ×2; Figure 70, interior, ×2; Figure 73, exterior, ×1. Figure 71: LACMIP 7850 from UCLA loc. 3622, paratype, cast of left valve interior showing pallial line, pallial sinus, and adductor muscle scars, ×1.5. Figure 72: LACMIP 7857 from UCLA loc. 3633, paratype, left valve, exterior, ×2. Figures 74, 75: LACMIP 7852 from UCLA loc. 3622, paratype, right valve; Figure 74, exterior, ×1; Figure 75, interior, ×2.

Figures 76, 77. *Califadesma tuscanum* sp. nov., LACMIP 7858 from UCLA loc. 4082, holotype, right valve. Figure 76: exterior, ×1. Figure 77: interior, ×1.5.

The specific name is from the Greek *aspris,* a type of oak, and refers to the occurrence of this species on the north side of Oak Run.

Califadesma elafium Saul, sp. nov.

(Figures 15, 62–75)

Diagnosis: Moderately elongate *Califadesma* with rounded posterior angulations and the posterior margin barely sinused between the angulations.

Description: Shell small, thick, bluntly wedge-shaped. Beaks low, opisthogyral, very near posterior end. Dorsal margin straight, anterior margin bluntly rounded, ventral margin nearly straight subparallel to dorsal margin, posterior margin broadly rounded, sinused between posterior angulations. Valves compressed anteriorly, truncated and inflated posteriorly; posterior with double angulation, more anterior of angulations sharper and stronger. Lunule long, narrow, and slightly depressed.

Hinge with short but well-developed flange-like nymph for external ligament and posteriorly directed resilifer immediately beneath beaks. Right valve with 3a and 3b thin, lamellar; 3a scarcely detached from hinge margin; AI and AIII elongate; PI elongate; PIII short, low. Left valve with slightly bifid triangular 2b and very thin lamellar 4a adjacent to resilifer; AII very long and lamellar, bimodal; PII short, striated. Pallial line rather distant from valve margin; pallial sinus a wide but shallow indentation extending from posterior muscle scar to point ventrally below beaks. Muscle scars subequal; posterior muscle scar round; anterior muscle scar elongate.

Holotype: LACMIP 7848.

Paratypes: LACMIP 7849–7853 from UCLA loc. 3622, 7857 from UCLA loc. 3633, Chico Creek, Butte Co., California; LACMIP 7854–7856 from UCLA loc. 4247, Oak Run, Shasta Co., California

Dimensions: Of holotype, LACMIP 7848, length 18 mm, height 9.9 mm, inflation of single valve 3 mm, length beak to posterior 6 mm; of paratype LACMIP 7852, length 16 mm, height 8.5 mm, inflation of single valve 3.5 mm, length beak to posterior 5.5 mm; of paratype LACMIP 7854, length 21.7 mm, height 13 mm, inflation of single valve 5.4 mm, length beak to posterior 5.7 mm.

Type locality: UCLA loc. 3622, Chico Creek, Butte Co., California.

Distribution: Musty Buck Member of the Chico Formation on Chico Creek (UCLA locs. 3621–3623, 3625, 3627, 3628, 3633; LACMIP locs. 10849, 10850, abundant at 3622 and 3623), Butte Co.; Redding Formation (UCLA loc. 4247) south side of Oak Run, Shasta Co., California.

Age: Santonian.

Remarks: In external shape this species is very similar to *Notodonax* (*Aliodonax*) *hsui* and *Adelodonax tectus* with which it occurs on Chico Creek (Figures 14, 15). It differs from both in having the double posterior fold and sulcus, and from *A. tectus* in being more inflated and having the ventral and dorsal margins more nearly parallel. *Califadesma elafium* is more elongate and less inflated than *C. aspris,* but less elongate and more inflated than *C. tuscanum.* In *C. elafium* the posterior angulations are more rounded and diverge more widely than those of *C. aspris,* and cardinal 3a is separated from lateral AII whereas in *C. aspris* these teeth are colaminal.

The specific name is from the Greek *elaphos* meaning "deer" or "stag," for its occurrence in the Musty Buck Member of the Chico Formation on Chico Creek.

Califadesma tuscanum Saul, sp. nov.

(Figures 76, 77)

Diagnosis: Elongate *Califadesma* of low inflation having the posterior margin straight between the angulations and with beaks at about the posterior third of the shell.

Description: Shell small, thick, bluntly wedge-shaped. Beaks low, opisthogyral, very near posterior end. Dorsal margins straight, sloping; anterior margin bluntly rounded; ventral margin nearly straight, subparallel to dorsal margin; posterior margin nearly straight between angulations, obtusely rounded. Valves compressed anteriorly, truncated and moderately inflated posteriorly; posterior with double, rounded angulations. Lunule long, narrow, and slightly depressed.

Hinge of right valve with short flange-like nymph for external ligament and posteriorly directed resilifer immediately beneath beaks. Cardinal teeth 3a and 3b thin, lamellar; 3a scarcely detached from hinge margin; AI and AIII elongate; PI elongate, PIII low, elongate.

Holotype: LACMIP 7858.

Dimensions: Of holotype, length 27 mm, height 14.6 mm, thickness 5.8 mm, length beak to posterior 9.2 mm.

Type locality: UCLA loc. 4082, Tuscan Springs, Tehama Co., California.

Distribution: Known only from the Chico Formation at Tuscan Springs, on Little Salt Creek, Tehama Co., California.

Age: Campanian.

Remarks: This species is described from a single right valve lacking most of its shell. The specimen preserves the valve shape, the placement of the double posterior angulation, and most of the hinge teeth which have been only partially exposed as more cleaning of the hinge would
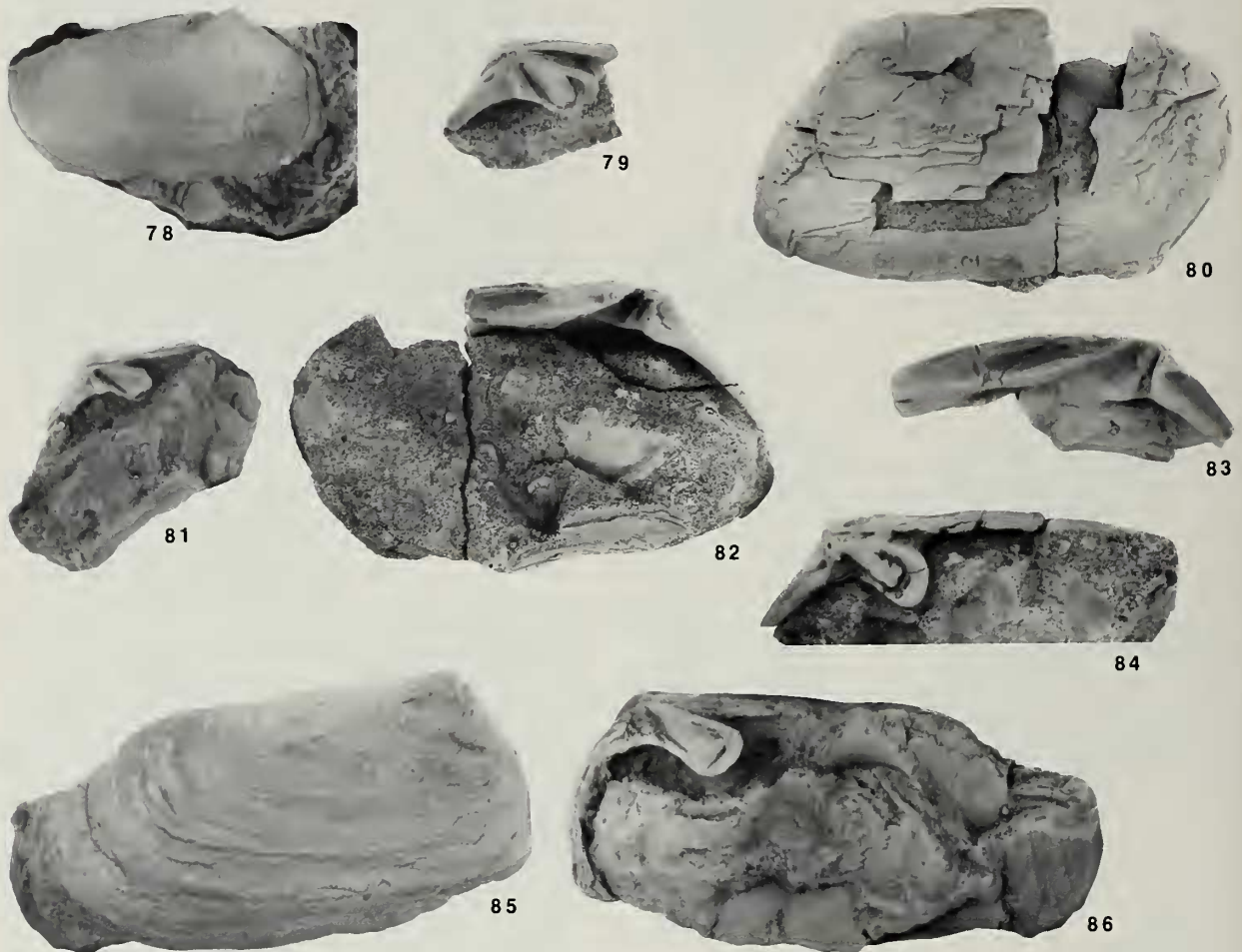
Explanation of Figures 78 to 86

Figure 78. *Myadesma pacifica* (Hall & Ambrose, 1916), CAS 61804.01 from Alameda Creek, Alameda Co., California, holotype, left valve, pallial line and sinus, ×1, middle Miocene.

Figures 79–84. *Myadesma dalli* Clark, 1922, Vancouver Island, British Columbia, upper Oligocene (Moore, 1984, includes the Sooke Formation in the Juanian Stage), ×1. Figure 79: CAS 61805.04, paratype, left valve hinge with lithodesma? in salient resilifer. Figures 80, 82: CAS 61805.01, holotype, right valve; Figure 82, showing foramen in beak and deeply depressed re-

silifer. Figure 81: CAS 61805.02, paratype, hinge of left valve. Figure 83: CAS 61805.03, paratype, hinge of right valve showing foramen in beak. Figure 84: CAS 231.01, paratype, hinge of left valve with lithodesma? in salient resilifer.

Figures 85, 86. *Myadesma howei* Clark, 1922, UCBMP 30328 from UCB loc. 3622, near Eugene, Oregon (Hickman, 1969:73, did not collect this species from the Eugene Formation and considers its occurrence there questionable), lower Oligocene, holotype, left valve, ×1. Figure 85: exterior. Figure 86: hinge.

break the specimen. The pallial line and posterior adductor muscle scar are not apparent on this specimen, but the position of the anterior adductor muscle scar can be determined. The outline of Gabb's (1864:pl. 23, fig. 138) *Tellina quadrata,* a species Gabb (1864:159) described from a single Tuscan Springs specimen that he considered to be a right valve, resembles that of *Califadesma tuscanum.* Gabb wrote "muscle scars and pallial sinus almost invisible on cast" and did not draw muscle scars or pallial line on his figure. He considered that the beak was nearer the obliquely subtruncated anterior end and did not mention the presence of a double fold on the posterior slope. Stewart (1930:7) was unable to find Gabb's original

material, and Gabb's statements suggest that despite the similar outline and same type locality *C. tuscanum* is not *T. quadrata.*

Califadesma tuscanum differs from *C. elaphium* in having beaks farther from the posterior end and being less inflated. It differs from *C. aspris* in having a nearly straight ventral margin. Of the three species, it has the lowest, most divergent posterior angulations.

Molluscan species extracted from the pebbly sandstone at Tuscan Springs are indicative of diverse shallow-into-deep-water habitats. Russell *et al.* (1986:190) consider these deposits to be a debris flow containing a shallow marine fauna comparable to their *Cymbophora suciensis*

assemblage. Collections include, however, species and genera typical of both deeper and shallower water than that assemblage; and no collection I have used contains *Cymbophora suciensis*. The presence of the littoral *Califadesma tuscanum* in these probable outer shelf deposits strongly suggests down slope displacement.

The species is named for its type locality, Tuscan Springs, Tehama Co., California, a spa on Little Salt Creek at the turn of the century (Waring, 1915:289).

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APPENDIX 1

LOCALITIES CITED

Geographic areas of the cited localities are plotted on Figure 1. Type localities of species described in this paper are fully described. Previously published localities are briefly characterized and the reference given.

213   CAS: 12 mi. W of Sooke, in the seacliff immediately E of the mouth of Coal [Kirby] Creek, Vancouver Island, British Columbia. Sooke Formation. Oligocene.

3314   UCLA: Float in creek bed at UCLA loc. 3313, S side Deer Valley, 2100′S, 28°W of NE cor. sec. 24, T1N, R1E, Antioch South Quad., Contra Costa Co., Calif. 37°55′11″N, 121°48′26.5″W. Coll.: W. P. Popenoe, August 1944. Great Valley Series, Deer Valley Formation of Colburn. Late Maastrichtian.

3621   UCLA: E of Chico Creek Co. road in upper part of meadow to N of old prune orchard, 2050′S, 2350′W of NE cor. sec. 12, T23N, R2E, Paradise Quad., Butte Co., Calif. 38°52′07″N, 121°42′05″W. Coll.: L. R. & R. B. Saul, 1952. Chico Formation, Musty Buck Member. Early Santonian.

3622   UCB: Smith's Quarry, between Millrace and Franklin Blvd., Eugene, 0.7 mi. E of BM 449, sec. 33, T17S, R3W, Oregon. Eugene Formation. Oligocene.

3622   UCLA: First ravine to S of Mickey's Place on "trail" about 0.2 mi. above W side Chico Creek, approx. 800′N, 1400′E of SW cor. sec. 1, T23N, R2E, Paradise Quad., Butte Co., Calif. 39°52′27″N, 121°42′24″W. Coll.: L. R. & R. B. Saul, 1952. Chico Formation, Musty Buck Member. Early Santonian.

3623   UCLA: Chico Creek, Paradise Quad., Butte Co., Calif. 39°51′51″N, 121°42′29″W. Chico Formation, Musty Buck Member. Early Santonian. (MATSUMOTO, 1960:155)

3624   UCLA: Chico Creek, Paradise Quad., Butte Co., Calif. 39°52′28″N, 121°42′31″W. Chico Formation, Musty Buck Member. Early Santonian. (POPENOE & SAUL, 1987:35)

3625   UCLA: Chico Creek, Paradise Quad., Butte Co., Calif. 39°51′47″N, 121°42′33″W. Coll.: L. R. & R. B. Saul, 1952. Chico Formation, Musty Buck Member. Early Santonian. (POPENOE et al., 1987:99)

3627   UCLA: Chico Creek, Paradise Quad., Butte Co., Calif. 39°51′26″N, 121°42′32″W. Chico Formation, Musty Buck Member. Late Santonian. (MATSUMOTO, 1960:156)

3628   UCLA: Chico Creek, Paradise Quad., Butte Co., Calif. 39°51′19″N, 121°42′33″W. Coll.: L. R. & R. B. Saul, 1952. Chico Formation, Musty Buck Member. Santonian. (POPENOE et al., 1987:99)

3633   UCLA: Chico Creek, Paradise Quad., Butte Co., Calif. 39°51′14″N, 121°42′24″W. Chico Formation, top of Musty Buck Member. ?Late Santonian, *Baculites capensis* Zone. (MATSUMOTO, 1960:15, 156)

3958   UCLA: S side of Deer Valley, sandstone lens in conglomerate, same ridge as UCLA 3957, but about 700′ farther S along crest of ridge, 2350′N, 750′W of SE cor. sec. 24, T1N, R1E, Antioch South Quad., Contra Costa Co., Calif. 37°55′01.5″N, 121°48′24″W. Coll.: W. P. Popenoe, 1944. Great Valley Series, Deer Valley Formation of Colburn, 1964. ?Late Maastrichtian.

3959   UCLA: Hard sandstone outcrop on crest of same ridge as UCLA loc. 3957, 400′S of UCLA loc. 3957, S side Deer Valley, 2580′S, 690′W of NE cor. sec. 24, T1N, R1E, Antioch South (1953) Quad., Contra Costa Co., Calif. 37°55′04″N, 121°48′23.5″W. Coll.: W. P. Popenoe, 1944. Great Valley Series, Deer Valley Formation of Colburn, 1964. ?Late Maastrichtian.

3960   UCLA: Hard sandstone bed just above conglomerate, S side of Deer Valley on first ridge W of UCLA locs. 3957, 3958, 3959, 2550′S, 35°W of NE cor. sec. 24, T1N, R1E, Antioch South Quad., Contra Costa Co., Calif. Probably same bed as UCLA 3958. 37°55′08″N, 121°48′34″W. Coll.: W. P. Popenoe, 1944. Great Valley Series, Deer Valley Formation of Colburn, 1964. ?Late Maastrichtian.

4082   UCLA: Tuscan Springs, on Little Salt Creek, about 10 mi. NE of Red Bluff, approx. 900′S, 1650′W of NE cor. sec. 32, Tuscan Springs Quad., Tehama Co., Calif. 40°14′29″N, 122°06′35″W. Chico Formation.

Early Campanian. (STEWART, 1927:292; SAUL, 1978: 57)

4104 UCLA: N side of Oak Run, Millville Quad., Shasta Co., Calif. 40°37′53″N, 122°06′W. Redding Formation, Member IV of Popenoe. Coniacian. (POPENOE & SAUL, 1987:36)

4106 UCLA: N of Clover Creek, Millville Quad., Shasta Co., Calif. 40°37′20″N, 122°03′26″W. Redding Formation. Early Santonian. (POPENOE, 1983:760, 765)

4247 UCLA: SE side of Oak Run, about 600′N, 1600′E of SW cor. sec. 15, T32N, R2W, Millville Quad., Shasta Co., Calif. 40°37′30″N, 122°04′52″W. Coll.: W. P. Popenoe, 31 Aug. 1959. Redding Formation, Member V in coarse gritty sandstone about 50′ below base of thick conglomerate bed. Early Santonian.

4347 UCLA: Sandstone cropping out below high tide line about 0.5 mi. N of Bolsa Point and just S of Spring Bridge Gulch, Pigeon Point Quad., San Mateo Co., Calif. 37°12′16″N, 122°24′16″W. Coll.: L. R. & R. B. Saul, 1947. Pigeon Point Formation. Campanian.

4671 UCLA: Sandstone cropping out along ridge top 100–200′ below base of Paleocene, S side Deer Valley, 2200′S, 600′W of NE cor. sec. 24, T1N, R1E, Antioch South (1953) Quad., Contra Costa Co., Calif. 37°55′06.5″N, 121°48′23.5″W. Coll.: W. P. Popenoe, 1962. Great Valley Series, Deer Valley Formation of Colburn, 1964. Late Maastrichtian.

5659 LACMIP: Little Stave Creek, shells and shark's teeth in light gray-green glauconitic sand and silt, approx. 5′ above base of 25′ cliff at end of 0.25-mi. long trail which begins at W end of West Point Drive near University of Alabama Historical Marker, Clark Co., Alabama. Coll.: Bruce & Joann Welton, 4 Sept. 1975. Claiborne Group, Gosport Sand. Middle Eocene.

6359 UCLA: W side San Joaquin Valley, just S of Salado Creek, 2000′S, 2650′E of NW cor. sec. 15, T6S, R7E, Orestimba Quad., Stanislaus Co., Calif. 37°24′57″N, 121°11′12″W. Coll.: R. B. Stewart & W. P. Popenoe, 1944. Moreno Formation, Garzas Sand. Maastrichtian.

6360 UCLA: W side San Joaquin Valley, draw S of Black Gulch, 1700′S, 1850′E of NW cor. sec. 34, T5S, R7E, Orestimba Quad., Stanislaus Co., Calif. 37°27′34″N, 121°11′21″W. Coll.: R. B. Stewart & W. P. Popenoe, 1944. Moreno Formation, Garzas Sand. Maastrichtian.

6489 UCLA: 3750′S, 14°E of buildings on Moffett Ranch in Orestimba Creek, in medium grained pepper-and-salt sandstone on crest of long N–S ridge near N end, 2490′S, 1000′E of NW cor. sec. 35, T7S, R7E, Orestimba Quad., Stanislaus Co., Calif. 37°17′N, 121°10′32″W. Coll.: W. P. Popenoe, 29 Aug. 1944. Moreno Formation, Garzas Sand. Maastrichtian.

7137 UCLA: Fossiliferous, hard calcareous concretion from sandstone beds in graben? (*Coralliochama* beds in sea cliff on both sides of graben?) about 200′ eastward along shore from sandy ravine with road to beach, N side Punta Banda Peninsula, Baja California Norte, Mexico. Coll.: John Alderson, 18 March 1984. Rosario Formation. Early Maastrichtian.

8133 LACMIP (=CIT loc. 1034, UCLA loc. 4104): Hard, cemented sandstone slabs weathering out of siltstone in pasture a little W of N of Hathaway Ranch house, about 1500′S, 1400′E of NW cor. sec. 16, T32N, R2W, Millville Quad., Shasta Co., Calif. 40°37′53″N, 122°06′W. Coll.: W. P. Popenoe & W. Findlay, 1933. Redding Formation, Member IV of Popenoe. Coniacian.

8148 LACMIP (=CIT loc. 1896): Type Garzas, Garzas Creek, Pacheco Pass Quad. (1947), Stanislaus Co., Calif. Approx. 37°13–15′N, 121°07–09′W. Coll.: W. P. Popenoe, 1944. Moreno Formation, Garzas Sand. Maastrichtian.

10846 LACMIP (=CIT loc. 1014): Right bank of Chico Creek, about 1 mi. upstream from bridge across creek below Mickey's house, NE ¼ sec. 1, T23N, R2E, Paradise Quad., Butte Co., California. Coll.: Popenoe and Scharf, 6 Aug. 1931. Chico Formation, Ponderosa Way Member. ?Coniacian.

10847 LACMIP (=CIT loc. 1016): Chico Creek, Paradise Quad., Butte Co., Calif. 39°52′28″N, 121°42′28″W. Coll.: L. R. & R. B. Saul, 1952. Chico Formation, Musty Buck Member. Early Santonian.

10849 LACMIP (=CIT loc. 1017): W side of Chico Creek, Paradise Quad., Butte Co., Calif. 39°52′47″N, 121°42′23″W. Chico Formation, Musty Buck Member. Santonian (POPENOE et al., 1987:98)

10850 LACMIP (=CIT loc. 1313): E side Chico Creek, Paradise Quad., Butte Co., Calif. Approx. 39°51′38″N, 121°42′18″W. Chico Formation, Musty Buck Member. Santonian (POPENOE et al., 1987:99)

28629 LACMIP: S of Easter Cross on W side of ridge which extends S from Mt. Soledad along W side of Rose Canyon, S of prominent amphitheater facing Rose Canyon, 7050′N of T16S, 1100′E of R3W, La Jolla Quad., San Diego Co., Calif. 32°50′15.1″N, 117°13′59″W. Coll.: M. P. Kennedy, 1967? Cabrillo Formation. Maastrichtian.

61804 CAS: Alameda Creek, 1.5 mi. S of Welch Cr., Pleasanton Quad., Alameda Co., Calif. Monterey Sandstone. Mid Miocene.

61805 CAS: Seacliffs between mouths of Muir and Coal Creeks, W of Otter Point, Sooke, Vancouver Island, British Columbia. Sooke Formation. Oligocene.